THE USE OF REACTION TIME TO ASSESS COGNITIVE FUNCTIONING OF LEARNING DISABLED CHILDREN

by

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CHAPTER I

Introduction: Problem and Rationale

Children with learning problems have challenged educators since the advent of public education. Almost every classroom teacher has had to cope with daily frustrations following failures to plan and provide effective learning experiences for this complex group of children. The child with a "learning problem" has been viewed from numerous perspectives, resulting in a wide assortment of labels to describe the learning disabled child. In fact, forty different terms have been identified as descriptions of children with learning problems (Cruickshank, 1972). Such terms have resulted from attempts to differentiate a particular problem learner from already existing exceptionalities including the mentally retarded, emotionally disturbed, physically impaired, and sensory handicapped.

Whether or not a child is labeled "learning disabled" often depends upon the professional orientation of the person doing the labeling (e.g., physician, school psychologist, reading specialist, or graduate student). Included among the various labels applied to the child exhibiting learning problems are "minimal brain damage" (Tredgold, 1908), "hyperkinetic syndrome" (Laufer & Denhoff, 1957), "dyslexia" (Haring & Miller, 1969), and "learning disabilities" (Kirk & Bateman, 1962).

Thus, the child with learning difficulties has been labeled many different ways, and like the labels, this special child has been treated in many different ways. The search for brain dysfunctions was among the initial approaches to defining causes and cures of learning disabilities. However, while a neurological examination of some learning disabled children revealed the existence of "abnormal brain waves", other children exhibiting similar abnormal behaviors did not show such abnormalities on the neurological examination. Thus, educators' attention has been directed at identifying discrepancies within the child's development of mental abilities. Identification of these discrepancies has been reflected in the wide acceptance and application of standardized instruments. Unfortunately, test results have not always indicated a child's areas of deficiencies, especially in information processing abilities. Furthermore, an incorrect response on a standard instrument may reflect any one of a variety of possible cognitive deficiencies (cf., Owen, Braggio & Ellen, 1976). Thus, it is advantageous for researchers to develop alternative approaches for understanding childrens' cognitive functioning. The purpose of this study was an attempt to differentiate the cognitive functioning of learning disabled and normal children during information processing by studying reaction time data.

Reaction time is used frequently by cognitive psychologists because it represents a direct measurement of mental processing (cf., Pachella, 1974). That is, reaction time, the latency between a stimulus and a response, is a measure of the duration of presumed cognitive processes intervening between a stimulus and a response. All other dependent variables used in human information processing research are indirect measures of psychological processing. For example, differential rates of correct response of particular types of errors in a learning or memory task are presumed to reflect the occurrence of particular cognitive activities.

Donders' Subtractive Method (1969) for isolating independent stages of cognitive functioning consists of measuring reaction latencies in different tasks, each task presumed to involve a processing stage not included in the other tasks. For example, Donders' c-reaction (termed selective reaction time) occurred when a subject was required to execute a response as fast as possible when one critical stimulus from a set of five possible stimuli was presented and not to react when any other stimulus of the set occurred. The latency between the critical stimulus and the identification response was presumed to measure the duration of three independent, cognitive stages: stimulus orientation (or attention), stimulus encoding, and response execution. On the other hand, for Donders' a-reaction (termed simple reaction time) only one stimulus alternative was presented on each trial and therefore the subject did not have to encode the stimulus before executing the response. Thus, with Donders' Subtractive Method the time duration for stimulus encoding was determined by subtracting the mean latency for an a-reaction (simple reaction time) from the mean time for a c-reaction (selective reaction time).

When Donders' subjects were required to identify which one of five possible stimulus alternatives was presented on each trial, four independent mental stages were assumed to intervene the stimulus presentation and the identification response: stimulus orientation, stimulus encoding, response selection (or decision), and response execution. Thus, by subtracting the time to make a c-reaction from the time to make an identification response in this latter situation (termed a b-reaction or choice reaction time), Donders determined the duration of the response selection process.

More recently Sternberg (1969) introduced a fourth type of reaction time task which presumably involves an additional stage of cognitive processing, i.e., memory search. The Sternberg paradigm, commonly referred to as a memory search task, requires the subject to memorize a short list of items (e.g., from one to five digits); and a trial consists of either the presentation of one of these memory items or the presentation of another, noncritical item. Following each stimulus presentation the subject makes one of two responses as quickly as possible, identifying whether or not the presented item is a member of the critical memory set (i.e., one response is made to items included in the memory set, whereas another response occurs to stimuli from without the memory set).

Sternberg's memory-search task presumably involves the following cognitive stages: (a) stimulus orientation, (b) stimulus encoding, (c) memory search and comparison, (d) response selection, and (e) response execution. Hence, the memory-search task involves each of the stages presumed to occur in Donders' choice reaction time task, with the addition of a fourth process: memory search and comparison. According to Sternberg (1969) the memory search and comparison stage involves an exhaustive mental comparison of the encoded stimulus with each of the critical memory-set stimuli stored in short term memory. Assuming that memory search and comparison is the only "extra" cognitive stage involved in the memory-search task that is not also included in choice reaction time, then subtracting choice reaction time from memory-search reaction time should reflect the amount of time one takes to mentally search a list of digits stored in memory. To the author's knowledge no one has documented such a comparison between reaction time in Donders' choice reaction time task and Sternberg's memory-search task, but the logic follows directly from Donders' classic Subtractive Method for isolating cognitive processing stages.

Purpose of the Study

The proposed research attempted to differentiate the cognitive functioning of learning disabled and normal children during information processing by studying reaction time data. Reaction time is a dependent variable used frequently for the study of normal, adult, human cognitions, but has been rarely used to study the cognitions of children, and perhaps has never been used systematically to differentiate the components of information processing among learning disabled (LD) children. The proposed research applied the logic that cognitive psychologists have used to differentiate cognitive functioning with reaction time data in order to study the "special" cognitive functioning of LD children. The search is exploratory since such an application of cognitive theory to the understanding of learning disabilities has not been previously documented. However, the application of an established methodology to differentiating the cognitive functioning within LD children and between LD and normal children would have important theoretical implications and urgent applied benefits.

The investigation obtained response latencies from normal and LD children in the following four different reaction time tasks, each successive task presumed to involve an additional stage of cognitive functioning: (a) simple reaction time, (b) selective reaction time, (c) choice reaction time, and (d) memory-search reaction time. Then, by using Donders' Subtractive Method the duration of time that each child took to encode a stimulus, search through memory, and decide which of two possible responses to execute was estimated. For diagnostic purposes reaction time data were transformed to represent the proportion of time spent completing each cognitive process. The validity of such a procedure for diagnosing cognitive deficiencies among LD children was studied by comparing each child's data with his or her history of learning difficulties. Furthermore, the reaction time performance of a group of LD children was compared between LD individuals in order to determine the extent to which consistent cognitive deficiencies are observed. It was particularly instructive to compare the various reaction latencies of the LD group with those from a group of "normal" children (matched on sex, grade level, chronological age, and mental age).

Hypotheses

The null hypothesis for the simple RT task was that mean RT would not be different for the LD and normal groups of children.

For the selective RT task the null hypothesis was that mean RT would not differ for the LD and normal groups of children.

The null hypothesis for the choice RT task was that mean RT would not be different for the LD and normal children.

For the memory search RT task two null hypotheses were appropriate:

1. Mean RT for each memory set size would not differ for the LD and normal children;

2. The intercept and the slope of the function relating RT to memory set size (1, 3, and 5) would not be different for the LD and normal groups.

CHAPTER II

Review of Literature: Learning Disabilities and Reaction Time

The present research used reaction time data to determine the relative importance of particular cognitive functioning during information processing by LD children, and to compare such processing with that of normal children. Reaction time paradigms have been used frequently by cognitive psychologists to study sequential stages of information processing for normal adults. However, the present study was an initial attempt to adapt such RT measures for studying the cognitive functioning of LD children.

Educators have commonly considered test scores and/or incorrect responses as indicative of information processing abilities. However, a more sensitive and direct measure of information processing is needed to differentiate the information processing of LD and normal children. This chapter reviews the literature that indicates the urgent need for more precise definitions and measurements of learning disabilities, and the research that supports the premise that the study of reaction time data may be an especially valuable approach to refining current diagnoses of LD children. This chapter will present the relevant literature in the following sections:

1. History and Labels
2. Definition of Learning Disabilities
3. Current Assessment Techniques
4. Information Processing
5. Related Reaction Time Studies and Research
6. Summary of the Review
7. Brief Definitions of Critical Terms Used in Present Study

History and Labels

In 1937 Samuel Orton presented his theoretical position that reading disabilities were due to a failure of the left hemisphere to become dominant, based on the observation of children who had difficulty remembering the order of letters and sounds. The term he used to describe this condition was "strephosymbolia".

From a study of brain-damaged soldiers Kurt Goldstein (1948) concluded that brain-damaged patients suffer "perceptual impairments" such as an inability to distinguish figure from ground. The area of learning disabilities known as "perceptual-handicaps" is a specific and direct outcome of Goldstein's observations and theorizing.

Influenced by Goldstein's writings were Alfred Strauss and Heinz Werner (1948), who speculated that learning could be inhibited by either damage to the brain or by some emotional trauma. Strauss often observed common behavioral patterns while working with mentally retarded, emotionally handicapped, and aphasic children. Specific characteristics of these patterns were: (a) perserveration or the inability to shift from one activity to another, (b) perceptual disorders such as figure-ground distortions, (c) conceptual disorders or an inability to organize thoughts, and (d) behavioral disorders such as hyperactivity and impulsivity. If these characteristics were observed and included either slight neurological signs (awkward gait, etc.), a medical history of pre-, peri-, or post-natal neurological impairment or no history of mental retardation in the family, Strauss theorized that the cause was exogeneous (an injury occurring outside of the genetic process) as opposed to endogenous (a genetically inherited malfunction).

With their publication Psychopathology and Education of the Brain Injured Child Strauss and Lehtinen (1947) took the etiological position that neurological malfunctioning is the basis of learning disorders. However, professionals in the LD field became dissatisfied with the label "brain-injured", because it is difficult to establish that a brain injury exists and such a position does not aid the educator in remediating learning problems. Therefore, Stevens and Birch (1957) suggested that "Strauss syndrome" be substituted for the term "brain injury". According to these authors the specific behavioral characteristics of children demonstrating this "Strauss syndrome" include the following: (a) erratic and inappropriate behavior following mild provocation, (b) increased motor activity disproportionate to the stimulus, (c) poor organization of behavior, (d) abnormal degree of distractibility under ordinary conditions, (e) faulty perceptions, (f) persistent hyperactivity, and (g) consistently awkward motor performance.

In 1966 Clements introduced the terms "minimal brain dysfunction" and "minimal neurological impairment" in the LD literature. Clements observed that children who exhibited characteristics similar to those identified as brain-injured evidenced no sign of brain injury. These children exhibited deviant learning and behavior patterns but demonstrated average ability on individually administered intelligence tests.

Educators in the field of reading have assigned children with severe reading deficiencies a variety of different descriptive labels including the following: "dyslexia", "specific reading disability", "primary reading retardation", or "strephosymbolia" (Haring & Miller, 1969). For example, the term "dyslexia" has been used by professionals since 1800 to describe the child who has severe difficulty learning to read without showing evidence of mental retardation or environmental deprivation. Initially, this term was used predominately to describe those children who had difficulties learning to read due to a neurological dysfunction. However, the word "dyslexia" is currently being used to define a variety of etiologies. For example, causes attributed to "dyslexia" have included brain injury, central nervous system (CNS) dysfunction, a genetic or inherited disorder, a maturational lag (e.g., Lerner, 1975). Other authors have excluded brain injury in their discussion of reading disabilities and have focused more on environmental determinants such as inappropriate classroom instruction (e.g., Rawson, 1971).

In 1967 Johnson and Myklebust proposed the term "Psychoneurological Learning Disability" for labeling special learning-deficient children. They assumed that a child's failure to learn to read, write, spell or do arithmetic was caused by an organic dysfunction. Presently, the most accepted term, "learning disabilities" was advocated by Kirk and Bateman in 1962 and later adopted by the Association for Children With Learning Disabilities and by the United States Office of Education (Wepman, Cruickshank, Deutsch, Morency & Strogher, 1976).

Definition of Learning Disabilities

The specific label assigned to an individual child exhibiting learning problems depends upon the orientation of the individual assigning the label. Unfortunately, the availability of such an assortment of labels doesn't always clarify the child's learning problems. Consequently, to avoid the ambiguity of a label the use of formal definitions has been advocated to provide a clearer understanding of a LD. However, advocating formal definitions as an attempt to be more specific about the LD child's handicap, has led to an array of definitions that seem to focus on many different dimensions. For example, the definition proposed by the National Institutes of Neurological Diseases and Blindness of the National Institutes of Health cosponsored by Task Force I used the following definition:

> The term "minimal brain dysfunction syndrome" refers in this paper to children of near average, average, or above average general intelligence with certain learning or behavioral disabilities ranging from mild to severe, which are associated with deviations of function of the central nervous system. These deviations may manifest themselves by various combinations of impairment in perception, conceptualization, language, memory, and control of attention, impulse, or motor function. (Clements, 1966, p. 9-10)

The focus of this definition is on the recent conceptualizations of "minimal brain dysfunction" as "a condition where an individual can exhibit similar characteristics to those individuals identified as brain injured but does not necessarily show any evidence of brain injury" (Clements, 1966, p. 11). However, educators no longer require the substantiation of a neurological problem, since the diagnostic labels "brain damage" and "minimal brain dysfunction" are often difficult to establish (Wallace & McLoughlin, 1975) and have little educational relevance for the application of corrective methods (Wepman, 1976).

Another dimension to the assessment and remediation of learning disabilities is the attention to certain task difficulties, which can be attributed to a neurological dysfunction, a behavioral disturbance, or to both as stated in the definition by Kirk (1962):

> A learning disability refers to a retardation, disorder, or delayed development in one or more of the processes of speech, language, reading, spelling, writing, or arithmetic resulting from a possible cerebral dysfunction and/or emotional or behavioral disturbance and not from mental retardation, sensory deprivation, cultural or instructional factors. (p. 263)

Another factor influencing the definition of a LD child is the identification of discrepancies within the development of mental abilities. Thus, one possible indication of a child's irregular development would be uneven performance on a variety of perceptual-motor and/or mental tasks (e.g., scatter within the subtests of the Wechsler Intelligence Scales) (Gallagher, 1966).

> Children with developmental imbalances are those who reveal a developmental disparity in psychological processes related to education of such a degree (often four years or more) as to require the instructional programming of developmental tasks appropriate to the nature and level of the deviant developmental processes. (p. 28)

Still another indication of LD is the existence of a disparity between the child's apparent intellectual potential and his academic performance as stated in the definition by Bateman (1965).

> . . . those who manifest an educationally significant discrepancy between their estimated intellectual potential and actual level of performance related to basic disorders in the learning processes, which may or may not be accompanied by demonstratable central nervous system dysfunction, and which are not secondary to generalized mental retardation, educational or cultural deprivation, severe emotional disturbance, or sensory loss. (p. 220)

Potential is defined by an individual's scores on an intelligence test, and performance is measured by the scores on an achievement test.

Finally, the National Advisory Committee to the Bureau of Education adopted one definition as specified by the 1969 Children With Specific Learning Disabilities Act, this is the definition adopted by Virginia's State Department of Education and states:

> Children with special learning disabilities exhibit a disorder in one or more of the basic psychological processes involved in understanding or in using spoken or written language. These may be manifested in disorders of listening, thinking, talking, reading, writing, spelling, or arithmetic. They include conditions which have been referred to as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexis, developmental aphasia, etc. They do not include learning problems which are due primarily to visual, hearing, or motor handicaps, to mental retardation, emotional disturbance, or to environmental disadvantage.

The fundamental points of this definition are as follows: (a) the child performs below his abilities as measured by an intelligence test (Bateman & Frankel, 1972). In other words, the child is functioning within the average or above-average range of intelligence but his present level of academic functioning does not reflect that potential; (b) the definition focuses on the child who will probably exhibit uneven performance on a variety of tasks (Bateman & Frankel, 1972). A profile of his subtest scores will probably indicate considerable scatter, being average or above average in some areas but significantly below average in other areas; (c) the definition considers the basic components of learning, i.e., the visual, auditory, tactile, motoric, and vocal process (Myers & Hammill, 1969); (d) this definition does not take an etiological position, and therefore it is not necessary for the educator to confirm a neurological dysfunction; (e) the definition includes an exclusion clause, eliminating children whose <u>primary</u> problems are due to mental subnormality, educational or cultural deprivation, severe emotional disturbance, and/or sensory deficit (Bateman & Frankel, 1972). However, there has been some controversy over this exclusion clause, since various researchers have indicated the presence of a learning disability among culturally disadvantaged children (Kappleman, Kaplan & Ganter, 1969) and deaf children (Auxter, 1971).

Even though the latter definition of LD is currently the most widely accepted, there is one particular aspect of the definition that can cause the educator some difficulty when attempting practical interpretations (cf., Myers & Hammill, 1976). Specifically, the aspect of the definition focusing on "psychological processes" is apparently an attempt to avoid identifying a neurological basis for the learning disorder (Wallace & McLoughlin, 1974). However, the definition of a psychological process is not always straightforward and operational.

Assessment of Learning Disabilities

Given a variety of labels for LD children, a variety of specific behavioral categories or symptoms have been identified as characteristic of the LD population. Actually, information had been collected from clinics and over 100 publications before a reasonable scheme for classifying LD behaviors was developed (Clements, 1966). The LD characteristics that have been most often cited in the literature include the following, listed in order of incidence frequency: (a) hyperactivity - the child engages in frequent motor activity that is not demanded by the situation and is disruptive to others; (b) perceptual-motor impairments - the child has difficulty in integrating visual or auditory stimulus with a motor act, such as copying a circle; (c) emotional stability - the child's temperament is variable and cannot be predicted from any observable stimulus situation; (d) general coordination deficits - the child is clumsy and ackward when engaging in either fine or gross motor skills; (e) disorders of attention - the child is distractible, attends to other auditory and visual stimuli than what the situation demands; (f) impulsivity - the child shows a lack of ability to restrain one's impulses, and the impulsive behavior is usually inappropriate for the situation; (g) disorders of memory and thinking - the child demonstrates poor ability to do abstract reasoning and shows difficulty in recalling information already learned; (h) specific learning disabilities - the child has difficulty learning to read, write, spell, or solve arithmetic problems; (i) disorders of speech and hearing - the child shows evidence of slow language development, reflected by difficulty comprehending or remembering spoken language, by mild speech irregularities, by inappropriate use of grammar, or by poor vocabulary knowledge; (j) neurological signs - the child demonstrates "soft" neurological deficiencies such as slow speech or poor coordination (Clements, 1966).

The selection of testing techniques for identifying children suspected of LD is often dependent on the philosophy of the person doing the testing. For example, some professionals advocate the medical-model approach by presuming that some underlying problem exists within the individual child that is affecting his or her ability to learn. For this medical-model approach the assessment challenge was to determine whether or not the child was brain-injured. However, such a search for brain-damage in LD children has been unsuccessful (Myklebust, Boshes, Oslon, & Cole, 1969), and indeed we can no longer presume that LD children have brain-damage.

Another model gaining popularity is the Behavioral Model (e.g., Skinner, 1975), which suggests an analysis of the child's responses as a function of specific environmental antecedents and consequences. This approach does not focus on underlying problems within the child but rather on the child's overt reactions to particular events. For example, when using this model the child's deficits are defined precisely in behavioral terms and the conditions preceding and following the problem behaviors are evaluated as events that possibly support the deficiency.

The use of behavioral checklists (see Appendix A) is a reflection of the behavioral approach to defining LD. More specifically, behavioral checklists are used to identify and record specific overt behaviors that impede the learning process and are often associated with children experiencing learning difficulties. This particular assessment tool is completed by the classroom teacher and reflects an estimation of the child's current classroom behavioral patterns. Certain clusters of behaviors from rating scales have been studied in relation to underachievement (Swift & Spivack, 1969). Indeed, a factor analytic study completed by Swift and Spivak (1969) organized behaviors described by classroom teachers into 12 behavioral factors. These factors included:

1. classroom disturbance
2. impatience
3. disrespect-defiance
4. external blame
5. achievement anxiety
6. external reliance
7. comprehension
8. inattentive-withdrawn
9. irrelevant responsiveness
10. creative-initiative
11. need for closeness to each other and
12. need achievement recognition.

Through the use of this scale the authors demonstrated that 63% of the children that were underachieving in school were deviant on four or more of the 12 factors, particularly on items 7, 10 and 11. Thus, the use of a behavior rating scale is a procedure for locating possible underachievers through the identification of observable behaviors that probably interfere with a child's learning.

Other professionals have adopted a statistical model, examining the child's scores on a variety of standardized tests and comparing them to those of other children (norm-referenced) or to some specified behavioral criterion of proficiency (criterion referenced). Remedial techniques would then tend to focus on what specific skills had not been devleoped or learned that are inhibiting the child from successfully reaching particular behavioral objectives.

Usually, the first step in the statistical diagnostic procedure is to secure a measure of the child's intellectual performance in order to determine whether the child's intellectual abilities are within the normal limits (i.e., an I.Q. of 90 or above). Either the Stanford-Binet Intelligence Scale (Terman, 1937) or the Wechsler Intelligence Scale for Children (Wechsler, 1974) are typically used to assess a child's intellectual performance for comparison with personal achievement. Wechsler's scale (WISC) tends to be more informative than the Standard-Binet for identifying LD children because it not only yields a global I.Q. score but also provides a verbal-performance dichotomy (Wechsler, 1974). In addition, the twelve subtests of the WISC provide the examiner with valuable information reflecting specific intra-individual abilities and disabilities.

The second step in the standard statistical evaluation is to determine the child's current level of academic functioning. Selection of appropriate achievement tests can be dependent upon the suspected area(s) of weakness as defined by teacher observations and/or uneven performance scores on the WISC. Two achievement tests widely used to provide a quick overview of academic functioning in reading, spelling and arithmetic are the Wide Range Achievement Test (Jastak & Jastak, 1965) and the Peabody Individual Achievement Test (Dunn & Markwardt, 1970).

A more indepth assessment of specific areas can be made through the use of various special diagnostic instruments. For example, a child suspected of a disability in math could be administered the KeyMath Test (Connolly, Natchman & Pritchett, 1973) and the results could provide educators with a profile indicating specific weaknesses and strengths in mathematical concepts. Also, a wide variety of diagnostic reading instruments, Gray Oral Reading Test (Gray, 1963), Spache Diagnostic Reading Scales (Spache, 1963), are available that provide an individualized reading profile, identifying specific areas that demand instructional remediation.

Often circumstances suggest the need for additional, special testing. For example, due to a poor or invalid testing situation or to vague and ambiguous test results, the educator may need more information about a possible disability. For example, a child might make errors on specific tasks measuring visual perception, auditory perception, or motor skills. To substantiate the existence of such a disability one of the following instruments could be administered:

The Purdue Motor Survey (Roach & Kephardt, 1966) indicates a child's motor development;

The Frostig Test of Visual Perception (Frostig, Lefever & Whittlesey, 1964) yields scores in five areas of visual perception (eye-hand coordination, figure-ground, form constancy, position in space, and spatial relations) to identify specific perceptual deficits that may be contributing to problems in reading, arithmetic, and handwriting;

The Motor Free Visual Perception Test (Collarusso & Hammill, 1972) reflects visual-perceptual development with the exclusion or motor involvement;

The Wepman Test of Auditory Discrimination (Wepman, 1958) measures auditory discrimination by recognizing the auditory differences in words.

The Illinois Test of Psycholinguistic Abilities (Kirk, McCarthy & Kirk, 1968) assess strengths and weaknesses in sensory of perceptual processing through the use of 12 separate subtests.

The results obtained from these tests provide useful information for determining those intervention strategies most appropriate for remediating the child's learning disability. For example, test results can indicate whether or not the child's learning problem is related to an inadequate intellectual ability; they can provide an indication of a preferred learning modality (i.e., auditory vs. visual); and they can indicate specific intra-individual differences within a given child.

On the other hand tests can provide ambiguous results concerning a deficiency in one or more of the psychological processes. For example, the observed behavior (i.e., child's test scores) is presumed to reflect a child's information processing abilities. This indirect method of labelling a child's cognitive style has been a serious concern of LD specialists. For example, research designed to determine the predictive validity of visual-perception tests have generated contradictory findings (Smith & Marx, 1972). In fact, the available evidence indicates that the visual perception tests are not particularly useful in predicting reading achievement beyond a first grade level (Ashlock, 1966; Chang & Chang, 1967; and Frostig, 1971). Furthermore, Larsen and Hammill (1975) and Hammill and Larsen (1974) reviewed the research exploring relationships between reading ability and performance on perceptual-motor tasks, and could not support the notion that visual or auditory-perceptual skills (as currently measured) are essential to academic success. In contrast to these approaches the proposed research attempted an application of reaction time methodology to define, measure, and understand the special perceptual and cognitive functioning of LD children.

Information Processing

There are a variety of descriptive labels (e.g., perceptual deficit, psychological processes) and several proposed learning models (Wepman, 1960; Osgood, 1953; Myers & Hammill, 1969) that reflect one of the most important questions in the field of learning disabilities. Specifically, how do children receive and process information from their environment? Once the possibility of a sensory deficit has been eliminated it is assumed by some that the inability to process sensory information is attributed to a perceptual deficit. Judgments are needed concerning the differential abilities a particular child exhibits in processing or understanding visual or auditory stimuli. Consequently, whatever terminology professionals tend to select when defining LD, the identification of "basic psychological processes" most often focuses on measuring specific perceptual skills presumed necessary for processing information.

It is considered by a number of professionals (Cruickshank, 1972; Frostig, 1972; Barsch, 1967; Kephardt, 1963; Getman, 1965; and Delacatto, 1966) that performance on perceptual-motor tasks determine higher cognitive development which in turn influences one's level of scholastic achievement. Therefore, it has often been presumed that once a child's perceptual deficit has been identified, it can be remediated, subsequently allowing the child to gain normal academic achievement. Consequently, the educational market has been flooded with a variety of perceptual training programs (e.g., Delacatto, 1966; Frostig & Horne, 1964; Kephardt, 1960; Barsch, 1965; Getman & Kane, 1964) specifically designed to remediate perceptual-motor and/or visual-motor deficits.

Recently, a number of researchers have studied the relationship between motor training and reading achievement (Spache, 1968; Harris, 1968), and concluded that no significant relationship exists. A similar conclusion resulted from reviews of 42 research studies designed to determine the efficacy of perceptual-motor training programs (Goodman & Hammill, 1973; Hammill, Goodman & Wiederholt, 1974). Most of these studies employed both Getman-type activities (e.g., general coordination, balance, eye-hand coordination, visual memory) and Kephart-type activities (e.g., walking a balance beam, jumping, hopping, identification of body parts). Based on the findings of 16 of the 42 studies that employed adequate research designs, the authors concluded that motor training procedures do not improve reading readiness, intelligence, academic achievement, or even perceptual-motor performance.

An alternative to the "perceptual deficit" approach to identifying and remediating LD have been the attempts to understand the psychological components involved in the information processing of LD children. An information processing model has been offered by Chalfant and King (1976). The three dimensions of this model include the (a) sensory input system, (b) response output system, and (c) intervening psychological processes (Chalfant & King, 1976). According to the authors, the sensory input system is responsible for transmitting information received by the various sensory channels (hearing, vision, touch and movement), whereas the response output system includes the individuals movements or verbal behaviors occurring as a result of stimulus input.

The authors define the intervening (non-observable) psychological processes as, ". . . a series of conditioned actions for: (a) analyzing sensory stimuli, (b) synthesizing these stimuli, (c) storing and retrieving stimuli, and (d) performing symbolic operations. These processes of perception, association, and expression form the basis of learning, thinking, and problem solving." (p. 38)

Other information processing models are similar in basic structure, but differ in terms of "labels" assigned to the processes. Even though there is a variety of terminology to express the dimensions of information processing, the essential features of the different models remain quite similar. For example, each model discusses the important dimension of receiving sensory information (input), doing something with that information (internal processing) and then finally executing a response, either vocally or motorically (output). A major goal of the present proposal was to differentiate the psychological processes involved during the information processing of LD and normal children.

Chalfant and King (1976) have identified five possible psychological processes intervening stimulus input and response output, including attention, discrimination, memory, sensory integration, concept formation, and problem solving. As discussed earlier these processes are not directly observable and the educator can only make inferences about the nature of these processes from direct observation of overt behavior. In fact, there are relatively few standardized instruments that can quantify a process dysfunction (Chalfant & King, 1976). For example, "attention" as defined by Chalfant and King is the ability to focus on relevant stimuli. This cannot be measured directly by currently available tests, but can be inferred by observing the subject's behavior during a testing situation (Chalfant & King, 1976) or by having the classroom teacher rate the child's attention-related behaviors on a checklist.

Owen, Braggio and Ellen (1976) have raised a provocative question regarding the incorrect responses of children during testing situations. They suggest that incorrect responses are not necessarily the result of inadequate knowledge or information but may be due to information processing dimensions of the task that interfere with a correct response (e.g., attention or memory). Therefore, an incorrect response may reflect a lack of knowledge, an attentional disorder, and/or a memory deficit. At the present time there are no reliable means of differentiating these different components involved in an information processing task.

Chalfant and King (1976) define "discrimination" as the ability "to respond differently to different stimuli" (p. 235). There are standarized instruments available to measure auditory (The Wepman Auditory Discrimination Test) and visual discrimination (The Illinois Test of Psycholinguistic Abilities; The Frostig Developmental Test of Visual Perception).

Memory is defined by Chalfant and King (1976) as "recognizing or recalling that which has been learned or retained" (p. 237) and is usually reflected by performance on tasks requiring the recall of recognition of designs, digits, objects, or sentences. The authors discuss two separate memory processes, short-term and long-term memory, and define these as follows:

> . . . short-term memory has the function of: (a) relieving the memory system of attending to moment-to-moment changes in the environment, and (b) temporarily storing information while it is manipulated, organized, rehearsed, or coded for long-term storage. Long-term memory receives and stores interpreted information for possible future retrieval and feeds retrieved information into short-term memory. (p. 237)

Chalfant and King (1976) define "sensory integration" as "incorporating two or more stimuli which are received through the same system" (p. 238), such as relating the word telephone to the ringing sound of the telephone. "Intersensory integration" refers to "incorporating two or more stimuli received through different channels" (p. 238), an example of auditory-visual integration being the association of the spoken word with the printed word. Ayres (1968) advocates that in order to read the child must be able to integrate sensory information from more than one modality (visual, auditory, tactile, and kinesthetic). Consequently, the cognitive breakdown for poor readers occurs between the input and output, when information must be transferred from one modality to another. Presently, there are no standardized instruments available to measure multiple stimulus integration, although Ayres' Southern California Sensory Integration Test (1972) represents the initial development of techniques to reliably measure sensory integration.

The last two psychological processes discussed by Chalfant and King (1976) include "concept formation" and "problem solving" which represent cognitive functioning that is significantly more complex than the information processing studied in the present research. Therefore, a discussion of these processes is beyond the scope of the present paper.

The present research was an attempt to measure separate information processing capabilities of LD children more directly and precisely than previously accomplished. Thus, through the application of Donders' Subtractive Method and Sternberg's Additive factor theory the reaction latencies were presumed to be a direct and sensitive measure of cognitive deficiencies among LD children.

Related Reaction Time Studies

Review of reaction time (RT) research (Smith, 1968) qualified the RT study according to certain task characteristics. The essence of these widely accepted characteristics which clearly define a RT study are as follows: (a) the latency between a stimulus presentation and a subject's response to that stimulus is a primary dependent variable, (b) the subject is informed that response latency is being measured and is told to respond as quickly as possible, (c) the emphasis is on speed of responding not frequency of errors, and therefore the relationship between each possible stimulus and its associated response is precisely defined (i.e., there is no uncertainty as to the appropriate response to a particular stimulus), (d) subjects practice making the designated responses to all possible stimulus presentations before latencies are measured, so as to maintain a low error rate (usually below 5%) during RT measurement (cf., Smith, 1968). For the present RT review, the author added two additional qualifications, namely that the RT study use children as subjects and that the stimulus events were presented visually (rather than auditorily or tactually).

Although RT is the dependent variable used most often in the study of human information processing (cf., Pachella, 1974), relatively few RT investigators have used children as subjects and only a small subset of the RT research with children studied the reactions of "abnormal" children. Furthermore, the author was not able to find a single study that compared a child's reaction latency between different RT tasks (such as is proposed in the current research), and only two RT publications used children with measured learning disabilities. Dykman, Walls, Suzuki, Ackerman, and Peters (1970) contrasted the simple RTs of 82 boys with learning disabilities with 34 academically adequate boys. More specifically, the task required the subject to press a telegraph key as rapidly as possible when a red light came on, and to release the key as fast as possible when a white light subsequently appeared. Simple RT was significantly faster for the normal than the LD children, and older children reacted faster than younger children.

The author found one other study that measured response latencies of LD children, but the subject's task did not really qualify as RT. Specifically, McGrady and Olson (1970) compared the performance of 31 LD children with 68 normal children on an automated battery of psycho-sensory tests. The visual tasks included the presentation of a standard stimulus and three comparison stimuli or the presentation of two pictures. For the former arrangement the subject pushed a button below the comparison stimulus that matched the standard, and in the second situation the subject pushed one of two buttons to indicate if the two pictures were the same or different. Although the latency between stimulus presentation and response was measured in both of these situations it is not appropriate to call the measurements RT because error rate was not low and in fact was the prominent dependent variable, and the subjects were not instructed to respond as quickly as possible. At any rate, the results of this study showed more errors and slower responding by LD children than the controls who matched the LD children on both chronological age (CA) and overall I.Q. on the WISC. It is noteworthy that the authors concluded their publication with the following: "Response time may be a more sensitive index than mere error scores for children with subtle learning disorders. This should be given further investigation" (p. 588).

The RT investigations that fit Smith's qualifications (1968) and used children as subjects may be classified according to five different tasks: simple RT, choice RT, memory-search RT, visual-search RT, and same-different RT. As discussed earlier, the proposed research will study each subject's performance in the first three of these RT categories, and include a fourth RT task (i.e., selective reaction time) of which the author could not find an example with children as subjects. Both the memory-search and visual-search tasks are based on Sternberg's RT paradigm (1969) in which the subject makes one of two responses to indicate whether a particular stimulus is included within a set of stimulus items. For memory search the critical stimulus set (usually from one to five items) is memorized and when a stimulus is presented it is presumably compared with the critical stimuli stored in short term memory. On the other hand, in visual search tasks the critical stimulus set is presented visually and the subject scans the items for the presence of absence of a pre-determined key item. For the same-different paradigm two stimuli (e.g., letters, digits, symbols, or pictures) are presented visually, and as quickly as possible the subject makes one response if the stimuli are the same and another response if the stimuli are different. Actually, according to Smith's (1968) criteria this same-different task doesn't qualify as an RT paradigm because the task involves a visual comparison between simultaneously presented events.

An inverse relationship between RT and age has been found with the simple RT paradigm (Elliott, 1970; Surwillo, 1971; Woodworth & Schlosberg, 1954), choice RT (Morrin & Forrin, 1965), and same-different RT (Hoving, Morin, & Konick, 1974). For example, Surwillo (1971) found nearly a three-fold decrease in simple RT over an age span of 4 to 17 years. Likewise, Elliott (1970) found an inverse relationship between simple

RT and children aged 5 to 13 (N = 216); and young adults (N = 72) reacted significantly faster than the children. Elliott emphasized the role of simple RT as a measure of attention, interpreting the age effects by presuming more distractibility among younger than older children and the most attentiveness for the young adults.

Of more relevance to the present research is the finding that eight subjects diagnosed as cultural-familially retarded (average CA = 21.3 and mean I.Q. = 58.5) responded significantly slower in a choice RT task than did a group of eight normal subjects matched according to CA (Silverman, 1975). Similarly, with the same-different RT paradigm, Silverman (1974) found slower reactions for a group of twelve familial retardates (average CA = 18.4 and I.Q. = 63.1) than for a group of eleven normal fifth-graders (average CA = 13.9) reacted significantly faster than the fifth-graders. The slowest subjects in this study were a group of eight second graders (average CA = 7.7).

Of particular relevance to the present research are the studies that compared the reaction latencies of "good" vs. "poor" readers. Such comparisons have been made with both the same-different and visual-search RT paradigms. Specifically, Krueger (1973) tested 12 college students and 12 fourth-grade pupils in a same-different RT task requiring subjects to indicate whether two adjacent uppercase letters (shown in either upright or upside-down orientations) were the "same" or "different" by pushing a right or left button as quickly as possible. The response latencies of the fourth-graders were nearly double that of the adult subjects; and for the fourth-grade group, RT decreased as the child's score on the Metropolitan Achievement Test increased.

Similarly, Spring (1971) found longer RT's among poor than normal readers on the same-different judgments of letter pairs.

The visual-search task requires the subject to remember a key stimulus item (e.g., word, letter, or digit) and to indicate as quickly as possible whether a display of one or more stimulus items contains the key item. The RT, or interval between stimulus display and "yes" or "no" response, includes the time to complete the following: orient or attend to the display, encode and search the items of the visual display for the key item, select the appropriate response, and execute the response. If the number of items in the visual display is varied within subjects in this situation, it is possible to distinguish between the latency to encode and search the visual display from the latency to accomplish all other processes involved in the RT task. Specifically, given that RT varies linearly with the number of stimuli in the visual display (e.g., Briggs & Blake, 1969; Katz & Wicklund, 1971), we have the following relationship:

$$RT = A + B(S)$$

where A is the y-axis intercept (representing the time to orient, decide, and execute), and B is the slope of the function relating RT to the number of stimulus items (S) in the display and reflects the time necessary to encode and search the visual display for the key item. The smaller the value of B, the flatter is the slope and thus the faster are the encoding and search processes.

On each trial of a visual-search task Katz and Wicklund (1971) required 40 fifth-grade students to indicate as fast as possible whether a key word was present in the stimulus display (a meaningful sentence of two, three, or five words long). For a group of 20 good and 20 poor readers (as defined by Iowa reading scores), the function relating RT to sentence length was linear, increasing with sentence length. The y-axis intercept was higher for poor than good readers, but the slope of the function was similar for both groups. Thus, the authors concluded that the differential reading achievement among their subjects was due to differences in orientation, decision, and/or execution processes and not to visual encoding and scanning. However, in a follow-up study Katz and Wicklund (1973) found no intercept nor slope differences between good and poor readers when requiring second and sixth-graders to scan rows of 1, 2, or 4 letters for a key letter. The second-graders did show a higher intercept and steeper slope than the sixth-graders, implying faster decisions and/or response executions and faster encoding and/or scanning by the older children. Similarly, when fourth-graders and college students searched for a critical letter in six-letter words and non-words, college students were significantly faster than fourth graders (Krueger, Keen, & Rublevich, 1974). However, in contrast to Katz and Wicklund (1973) and Spring (1971), Krueger et al., (1974) observed faster searches by the better readers in each age group. Since these authors did not vary the number of letters in the search display, it was not possible to differentiate RT differences due to stimulus encoding and visual search from those due to orientation, decision, and execution.

Whereas the slope of the function relating RT to display size reflects the execution speed of at least two cognitive processes (i.e., stimulus encoding and visual search), the slope of the RT function in the standard memory-search task (Sternberg, 1969) reflects rate of memory search independent of stimulus encoding. More specifically, in memory search RT tasks the subject memorizes a critical set of stimulus items, and when a probe stimulus is presented the subject makes one of two possible responses to indicate whether the probe is a member of the critical set. An increasing, linear relationship is usually found between RT and number of items in the critical set. The intercept of this function presumably reflects the time taken to orient to the probe stimulus, encode the probe, decide on the appropriate response, and execute the response; while the slope of this RT function represents memory search time. In fact, the reciprocal of this slope (i.e., 1/B = seconds/memory-set item) indicates the amount of time needed to search one memory-set item (cf., Sternberg, 1969).

As revealed by the present author's literature search, all of the published memory search experiments with children were designed primarily to study age differences, or the role of particular task characteristics. A common finding is that the y-axis intercept of the function relating RT to memory-set size decreases with increasing age (Baumeister & Maisto, in press; Hoving, Morin, & Konick, 1970; Maisto & Baumeister, 1975; Silverman, 1974). A majority of these recent memory-search studies have found no between-group differences in the slope of the linear functions relating RT to memory-set size, thereby implicating similar memory-search processing among the age groups studied; i.e., Hoving, Morin, and Konick (1970) for kindergarten, fourth-grade, and college students, Maisto and Baumeister (1975) and Baumeister and Maisto (in press) for pre-school, third grade, and fifth grade children, and Silverman (1974) for second, fifth, and eighth graders. Furthermore, Silverman (1974) showed slower RTs of retarded than normal children (matched on CA) to be due to an intercept difference (orientation, encoding, deciding, and/or execution) rather than a slope difference (memory search).

The fourth task of the proposed study will enable a comparison of memory search rates between normal and LD children. Prior research with other abnormal children suggests that the group memory-search rates in the proposed study will be similar. On the other hand, the prior RT research with the memory search paradigm suggests that the LD children will show higher RT intercepts than the normal children. Whereas, prior research did not differentiate between the cognitive components contributing to intercept differences (i.e., encoding, deciding, and executing), the present investigation will include three additional RT paradigms (simple, selective, and choice RT) and apply Donder's Subtractive Method (explained earlier) to partial out the relative roles of encoding, deciding, and executing as contributors to intercept differences. Indeed, since the memory search task presumably includes just one cognitive process not involved in choice RT (i.e., memory search or scanning) and since memory-search time is reflected in the slope of the function relating RT to memory-set size, an individual's RT intercept in the memory search task should be approximately equivalent to that individual's average choice RT.

Summary of Review

More and more workers in the area of learning disabilities are realizing that the various available labels are often inadequate descriptors for individual learning problems, that the LD child is not always clearly distinguishable from the non-LD, and finally that many of the standardized instruments may not be measuring the purported skills and such skills may not necessarily correlate with academic success.

To better understand why this average intelligent child is having special learning difficulties various professionals have tried to examine the LD child's brain, some have pondered over his/her standardized test scores, others have analyzed his/her classroom behaviors, but numerous diagnostic and remedial questions remain unanswered. More direct and sensitive methods for studying the LD child's information processing abilities are certainly needed for pinpointing specific areas of deficiency and assessing the efficacy of particular remedial strategies. The value of the present study was based upon this need for improved techniques to assess learning disabilities. That is, reaction latencies were compared among a variety of tasks presumed to involve differential cognitive processes. A major goal of the proposed project was to demonstrate the value of reaction times in pinpointing specific cognitive dysfunctions.

Brief Definitions of Critical Terms Used in Present Study

Learning Disabilities - a child who demonstrates academic performance that is significantly below his/her potential.

Reaction Time - latency in milliseconds between a stimulus presentation and the subject's appropriate response to the stimulus.

Normal Children - a child who demonstrates average or above average performance on both achievement and aptitude tests.

<u>Cognitive Functioning</u> - presumed mental activity intervened between a stimulus presentation and a reaction to that stimulus.

<u>Encoding</u> - the cognitive component of information processing that refers to discriminating one stimulus from another.

<u>Response Decision</u> - the cognitive component of information processing that refers to deciding which response is associated with the encoded stimulus.

<u>Memory Search</u> - the cognitive component of information processing that refers to serially searching through a list of items stored in memory in order to find a critical item.

CHAPTER III

Methods and Procedures

Selection of Subjects

Subjects for this research project included a total of 30 boys, 15 of which were labeled "learning disabled" and 15 which were considered "normal" (i.e., not experiencing any academic difficulty). The LD children were selected from local school divisions whose school officials had identified and officially labeled them as "learning disabled". Eleven of these 15 LD children were selected from an LD summer clinic sponsored by Virginia Polytechnic Institute and State University and the Montgomery County Schools. The remaining 4 LD children were not participants in this particular summer program but were officially labeled "LD" by school personnel and were receiving the special services of an LD teacher. Thus, the basic criterion for defining the LD population for this study was that the LD subjects had been officially labeled LD by appropriate school personnel and were currently enrolled in a special education class for LD children. These LD children also had the following characteristics: average or near average performance on an individually administered intelligence test (I.Q. 85 or above), and difficulty in at least one academic area (i.e., reading, spelling, handwriting, and/or arithmetic). Educational achievement test scores were available and showed a child's current achievement level in various academic areas. Each LD child showed a discrepancy between potential (as reflected by I.Q. and achievement in a particular area). As shown in Table 1 the mean grade placement for the LD group was 4 years-3 months, whereas the mean achievement scores in reading recognition (3.4), reading comprehension (3.5) and spelling (3.1) were approximately one-year below grade placement.

Insert Table 1 about here

The "normal" population included 15 boys from regular classrooms in either the Montgomery or Giles County elementary schools. These 15 boys were yoked to their LD counterparts according to I.Q., chronological age, and sex. The Slosson Intelligence Test for Children and Adults (SIT) was used by this researcher to estimate the I.Q.s of the normals because of its ease of administration and relatively high correlation (r = .61) with the Verbal portion of the WISC (Smith, 1974). Ten LD and normal children were matched on verbal I.Q. However, five of the LD children obtained relatively low verbal I.Q. scores and therefore, these LD children were matched with their normal counterparts on the Performance I.Q. score of the WISC.

I.Q. scores of ten points or less was selected as a cut-off for matching purposes. Consequently, if the verbal I.Q. of the LD child could not be matched within 10 points of a normal child's verbal I.Q. then the children were matched on their performance I.Q. Table 1 depicts both the verbal and performance I.Q.s of the LD population. The mean verbal I.Q. was 101 and the mean performance I.Q. was 103. As shown in Table 2 the mean verbal I.Q. of the normal children was 108. The performance I.Q.s of the normal children who were matched with LD children on the basis of performance I.Q. are listed in Table 2 and show a mean performance I.Q. of 101.

Insert Table 2 about here

Table 1

Characterisitcs of LD Children: Age, Grade, I.Q., Achievement and Teacher Reports

			I.Q.[a]		Achievement (Grade Level)[b]				Teacher Reports	
No.	Age	Grade	Verbal	Performance	Read Rec.	Read Comp.	Spell	Math	Exposure	Problem Area(s)
1	10.0	5[d]	87	91	2.8	3.2	3.8	3.8	6 wks.	Oral Reading
2	11.3	5[d]	102	115	5.2	5.3	2.7	5.7	6 wks.	Math Operations
3	9.0	3[d]	94	84	3.5	2.2	2.2	3.5	6 wks.	Oral Reading & Comprehen.
4	9.5	3[e]	82	105	1.4	2.1	1.7	2.5	6 wks.	Oral Reading & Writing
5	11.11	6	102	87	4.2[f]	-	4.5	4.5	6 wks.	Oral Reading
6	11.9	5[d]	78	106	3.1	2.7	2.9	3.0	6 wks.	Oral Reading & Comprehen.
7	9.11	5	118	131	3.8	3.1	3.2	4.4	6 wks.	Oral Reading & Comprehen.
8	8.3	3	122	114	2.2	2.2	3.8	1.8	6 mos.	Oral Reading & Writing
9	10.8	4[e]	107	108	2.8	2.9	2.4	5.7	6 wks.	Oral Reading
10	9.9	3[d]	85	98	1.8[f]	-	2.0	3.3	6 wks.	Oral Reading & Comprehen.
11	9.9	3[d]	109	100	3.6	3.6	3.3	4.4	6 mos.	Oral Reading & Listening
12	12.4	7	106	85	6.2	7.5	4.4	5.3	6 wks.	Math Operations & Memory
13	9.2	3[d]	97	107	2.6	3.5	3.4	5.3	6 mos.	Oral Reading
14	10.8	4[d]	92	108	3.5	3.6	2.7	4.9	6 wks.	Oral Reading & Comprehen.
15	10.8	5	130[g]	-	4.5[f]	-	3.9	8.2	6 wks.	Oral Reading
$\bar{X}$	10.3	4.3	101	103	3.4	3.5	3.1	4.4		

[a]Scores on the Wechsler Intelligence Scale for Children (WISC).
[b]Scores on the Peabody Individual Achievement Test (PIAT).
[c]Obtained from a questionnaire completed by the teacher working with the LD child at the time of the experiment.
[d]Repeated one grade.
[e]Self-contained class.
[f]Administered the Wide Range Achievement Test.
[g]Administered the Slosson Intelligence Test for Children and Adults (SIT).

Table 2

Characteristics of the Normal Children:
Age, Grade, I.Q. and Achievement

			I.Q.[a]		Achievement (Grade Level)[b]		
No.	Age	Grade	Verbal	Performance	Read. Rec.	Spell.	Math
1	10.1	5	97	-	7.0	5.3	4.2
2	11.5	6	116	108	7.0	7.7	5.9
3	8.6	3	101	-	2.7	2.5	2.8
4	9.1	4	93	98	3.5	3.0	3.0
5	12.2	6	108	98	9.7	9.2	5.2
6	12.4	7	117	101	7.5	6.3	5.9
7	9.11	4	120	-	8.1	8.7	5.2
8	8.8	3	114	-	4.7	3.2	3.6
9	10.10	6	113	-	9.7	5.0	5.2
10	9.11	4	106	105	3.6	3.5	4.2
11	9.7	4	108	-	6.5	5.7	4.2
12	12.8	7	96	91	8.1	8.2	5.3
13	9.5	4	105	-	3.8	2.6	4.2
14	10.9	5	103	105	6.8	6.3	5.5
15	11.0	5	120	-	6.5	5.3	5.0
$\overline{X}$	10.4	4.8	108	101	6.3	5.5	4.6

[a]Scores on the Slosson Intelligence Test for Children and Adults (for Verbal I.Q.) and the Wechsler Intelligence Scale for Children (for Performance I.Q.).

[b]Scores on the Wide Range Achievement Test (WRAT).

The I.Q. scores listed in Table 3 denote the I.Q. score selected for matching purposes for both groups of children. The I.Q. scores listed with an asterick denote that a performance I.Q. was selected for matching pruposes. Therefore, the mean I.Q. (106) listed for the normal subjects includes either a verbal or performance I.Q. Likewise, the mean I.Q. (106) of the LD subjects includes either a verbal or performance I.Q.

Insert Table 3 about here

Both the LD and Normal populations were matched on chronological age. Fourteen subjects from each group were matched chronologically within 4 months, the only exception being a normal subject who was 7 months older than his LD counterpart. As shown in Table 3 the mean C.A. for the normal group was 10 years-4 months and the mean C.A. for the LD group was 10 years-3 months.

The mean grade placement was 4 years-3 months for the LD group and 4 years-8 months for the normal group. The difference of 5 months between these two groups can be accounted for by the fact that 8 of the 15 LD children had been retained once in school and 2 LD children are currently enrolled in a self-contained LD class. Children placed in a self-contained setting are not able to function adequately in the grade they have just completed or are not expected to do well in the next promotion grade.

Prior to the experimental session parents of the children participating in this experiment were contacted by telephone and explained the nature of the experiment in which their child would be a participant.

Table 3

Mean Error Frequencies per Group as a Function

of the Reaction Time (RT) Condition

Reaction Time Condition	Normals		Learning Disabled	
	Response Errors[a]	Deadline Errors	Response Errors[a]	Deadline Errors
Simple RT	4.4	0	4.3	0
Selective RT	3.9	.20	3.1	.20
Choice RT (Dominant)	5.3	.47	5.0	.73
Choice RT (Nondominant)	4.5	.33	6.6	.17
Search RT MS-1 (Match)	.87	.13	.47	.33
Search RT MS-1 (No Match)	1.8	.13	1.3	.93
Search RT MS-3 (Match)	3.5	.67	3.2	.80
Search RT MS-3 (No Match)	3.2	1.0	2.9	1.3
Search RT MS-5 (Match)	5.0	.93	5.2	1.9
Search RT MS-5 (No Match)	4.7	2.7	6.8	2.5

[a]Anticipation responses for Simple RT and inaccurate identification for all other RT conditions (i.e., pulling the trigger to the wrong stimulus for selective RT and pulling the wrong trigger for the choice RT and search RT conditions.

Written parental permission was obtained on all participants. Furthermore, the parents of the LD children also signed a parental permission form that allowed the experimenter to obtain any school-related information relevant to the research project (i.e., I.Q. scores, achievement scores and teachers' evaluations). For the normal children parental permission was for the experimenter to administer the Slosson Intelligence Test for Children and Adults (SIT) and/or the WISC and the Wide Range Achievement Test (WRAT). It was understood by the parents that this information was necessary for matching purposes.

Prior to the experimental session each subject was asked if they would be willing to participate in an experiment at VPI&SU. They were told briefly about the experimental procedures, approximately how long it would take to complete the experiment and the toy the child would receive at the completion of the experimental session. The author transported the children to and from the location of the experimental session which was Derring Hall on the VPI&SU campus.

Reaction Time Tasks

One individual session, lasting approximately two hours, was required for each participant in this research project. At the time of the experimental session each participant was shown the RT equipment and given the opportunity to ask the experimenter any questions regarding the equipment. At this time the hand dominance of each child was determined. Of the thirty children, one LD child and one normal child was left-handed.

Each child performed four different RT tasks at this session; i.e., Simple RT, Selective RT, Choice RT and Memory-Search RT. Each RT task consisted of 10 warm-up trials and at least 100 data trials. During the 100 data trials an error tone sounded if the child made an anticipatory, deadline, or identification error. More specifically, the error tone sounded whenever reactions occurred prior to stimulus presentation (i.e., an anticipatory error), when reactions took longer than 1.5 sec. (i.e., a deadline error), and when the child pulled the wrong RT trigger. An extra trial was added for each error that the subject made, so that the total number of RT trials actually exceeded 100 per RT task. A one-min. break occurred after the first 50 data trials. At this time the child was able to stand and stretch and the experimenter verbally commended him for working so diligently. The sequence of events for each trial was as follows:

1. a .25 "ready" buzzer,
2. a time interval varying from .5 to 2 sec.,
3. a symbol illuminated by a 2.5 x 3.5 cm. digital readout, and
4. the child's left-hand or right-hand reaction trigger response to turn off the stimulus.

The interval between the stimulus presentation and the subject's response was measured to the nearest millisecond by a digital clock. Upon completion of the Simple and Selective RT tasks each child was provided a three-min. break in which he was allowed to move around, get a drink of water, etc. A ten-min. break was scheduled after the completion of Choice RT, which concluded half of the experimental tasks. At this time the experimenter provided the child with peanuts, a soft drink and a tour of the psychology department.

For Simple RT (the first task for every child), only one stimulus alternative occurred on each trial and only one reaction trigger was operative. Specifically, the child was instructed to pull the dominant-hand trigger as quickly as possible after seeing the symbol |‾|. If the child pulled the trigger before the stimulus presentation, a tone sounded and this response was recorded as an anticipation error. Following an anticipation error the experimenter reminded the child to react after the stimulus was presented and then the trial was repeated. (Refer to Appendix B for the Simple RT instructions.)

After 100 errorless, Simple RT trials (intervened midway by a one-min. break), the experimenter asked the child to be seated and then a read the instructions for the Selective RT task (see Appendix B for a copy of these instructions for Selective RT). For this task the stimulus presentations on each trial were [or], but the children held only one reaction trigger, i.e., the one corresponding to their dominant hand. Each child was required to pull the reaction trigger as quickly as possible following a presentation of the symbol [but to make no response to the symbol]. Since these stimulus alternatives were equiprobable, each occurring 50 times, the subject made 50 responses throughout the 100-event sequence. If the child pulled the reaction trigger to a], a tone sounded to indicate an identification or anticipation error.

After 100-errorless, Selective RT trials (with a one-min. rest period after 50 trials), the experimenter allowed for a three-min. break and then read the task instructions for Choice RT. (See Appendix B for the Choice RT instructions.) For this task the child was instructed to hold two reaction triggers, one in each hand, and to identify the occurrence of a |_| or |‾| symbol by pulling a particular trigger for each stimulus. Specifically, each child pulled the non-dominant trigger to a |‾| and a dominant trigger to presentations of |_|. An error tone sounded whenever the child responded before the stimulus occurred (i.e., anticipation error), and whenever the child pulled the wrong response trigger. Each stimulus alternative was equiprobable, occurring on exactly 25 trials within the two consecutive blocks of 50 trials.

After 100 errorless, Choice RT trials, a 10-min. break was provided, at which time refreshments and a walk through the psychology department were offered the child. The experimenter provided a considerable amount of verbal commendation and support in order to maintain the child's motivation to complete the subsequent RT tasks.

The final experimental task, Memory Search RT, was divided into three consecutive sets of 100 trials each. Prior to each 100-trial block the experimenter placed a 3 x 5 card in front of the child and repeated the digit(s) printed on the card. The digit(s) were referred to as critical numbers that the child needed to remember in order to perform the RT task. There was one critical number for the first 100 trials, three numbers for the second 100 trials, and five critical numbers for the third 100 trials. The instructions explained that the task was to identify whether the number presented on each trial was one of the critical numbers. (Refer to Appendix B for the instructions for memory search RT.) The trigger held with the dominant-hand was pulled as quickly as possible whenever a critical number occurred, while the nondominant-hand trigger was pulled to a noncritical stimuli. Ten practice or warm-up trials preceded each set of 100 trials, at which time questions concerning the child's task were answered.

For the first 100 trials the critical number was "1", and the noncritical number was "0". One of six possible stimulus alternatives occurred for the second block of 100 trials, the numbers 0, 2 and 5 being critical and 1, 3 and 4 being noncritical. For the last 100 trials of this task the critical digits were the numbers 1, 3, 6, 8 and 9 and the noncritical digits were 0, 2, 4, 5 and 7. For each 100-trial block the critical and noncritical stimuli were equiprobable, and therefore one-half of the stimulus presentations were critical digits and required a dominant-hand response. A one-min. break was provided after each block of 50 trials. After each block of 100 trials, a three-min. break occurred, at which time the child was encouraged to stand and stretch.

In summary, all four RT tasks, consisting of a total of 600 errorless trials, was completed in one, two-hour session. A one-min. break was provided after every 50 trials, and a three-min. break was provided after every 100 trials. Midway through the experiment (after 300 errorless trials) the child was provided with a 10-min. break which included some refreshments. Upon completion of the experimental session each child selected a toy and was thanked for his participation.

CHAPTER IV

Results

Errors

Two types of errors were possible for the Simple RT task, (i.e., an anticipation error and a deadline error). Anticipation errors occurred whenever the child pulled the reaction trigger before the stimulus was presented, whereas deadline errors were defined as responses which took longer than 1.5 sec. A third type of error was possible for the other RT tasks. This was an identification error which occurred whenever the child pulled the reaction trigger to the wrong stimulus. For Selective RT this meant that the child pulled the reaction trigger when s/he was not supposed to, and for the Choice RT and Search RT tasks identification errors occurred when the child pulled the wrong reaction trigger. As described in the procedure section, an error tone sounded whenever deadline or identification errors were made; and extra RT trials were run at the end of each RT task to substitute for the error trials (i.e., trials with anticipatory, deadline, or identification errors).

The errors for each child were categorized and tallied and the frequencies were studied with an analysis of variance. The mean error frequencies per group (i.e., Normal vs. LD children) are depicted in Table 4 as a function of the RT task. The first error column per Group (i.e., Response Errors) refers to anticipatory responses for the Simple RT task and identification errors for all other RT tasks. The errors for the Choice RT and Search RT tasks were dichotomized according to whether the dominant-hand trigger or nondominant-hand was pulled when the error was made.

Insert Table 4 about here

Anticipatory responses were extremely rare, except for the Simple RT task. That is, an average of about four anticipations occurred per child during Simple RT, but most children made no anticipations during the other RT tasks. For Simple RT no deadline errors occurred, and the between group comparison of anticipations indicated absolutely no group effect ($F = 0$).

Actually, as shown in Table 3 there were no substantial differences in error frequency due to group, nor to hand dominance. However, for each RT task the frequency of identification errors was consistently higher than the frequency of deadline errors; and for the Search RT task the numbers of identification and deadline errors increased as the size of the memory set increased. It is noteworthy that for both groups the frequencies of identification and deadline errors were markedly higher for the Choice RT task than for the Search RT task with one item in the memory set (i.e., MS-1).

The analysis of variance for the identification errors during Choice RT was a factorial of 2 (Groups) x 2 (Responses: Dominant vs. Nondominant), and showed no significant effects. The 2 (Group) x 2 (Response) analysis for the deadline errors during Choice RT also showed no significant effects (all $ps > .10$).

The analysis of variance of the identification errors during Search RT was a factorial of 2 (Groups x 2 (Responses: Dominant/Match vs.

Table 4

Comparisons for the Normal and LD Children: Age, Grade, I.Q., Achievement, Encoding and Decision

	Normal Children						LD Children					
No.	Age	Grade	I.Q.[a]	Ach.[b]	Encoding	Decision	Age	Grade	I.Q.[a]	Ach.[b]	Encoding	Decision
1	10.1	5	97	7.0	311	92	10.0	5	87	3.8	255	297
2	11.5	6	108*	7.7	159	169	11.3	5	115*	5.7	205	173
3	8.6	3	101	2.8	230	343	9.0	3	94	3.5	276	153
4	9.1	4	98*	3.5	191	60	9.5	3	105*	2.5	136	73
5	12.2	6	108	9.7	207	125	11.11	6	102	4.5	198	99
6	12.4	6	101*	7.5	154	131	11.9	5	106*	3.1	166	330
7	9.11	4	120	8.7	166	107	9.11	5	118	4.4	233	261
8	8.4	3	114	4.7	265	188	8.3	3	122	3.8	253	195
9	10.10	6	113	9.7	113	101	10.8	4	107	5.7	172	53
10	9.11	4	105*	4.2	191	119	9.9	3	98*	3.3	268	84
11	9.7	4	108	6.5	103	157	9.9	3	109	4.4	263	29
12	12.8	7	96	8.2	172	181	12.4	7	106	7.5	161	225
13	9.5	4	105	4.2	89	143	9.2	3	97	5.3	324	52
14	10.9	5	105*	6.8	165	248	10.8	4	108*	4.9	233	204
15	11.0	5	120	6.5	104	183	10.8	5	130	8.2	209	234
$\overline{X}$	10.4	4.8	106	6.5	175	156	10.3	4.3	106	4.7	233	164

[a]Verbal I.Q. (Wechsler Intelligence Scale for Children for LDs and Slosson Intelligence Scale for Children and Adults for Normals) except for pairs 2, 5, 6, 10 and 14 where children were matched on performance I.Q. of the WISC.

[b]The highest achievement score on the WRAT for Normals and the PIAT for LDs.

Nondominant/No-Match) x 3 (Memory-Set Sizes: 1, 3, or 5 digits); and only a main effect of memory-set size was obtained, F (2, 56) = 23.86, $p < .001$. Error frequency increased substantially as a function of Memory-Set Size; means being 1.1, 3.2 and 5.4 for set sizes of 1, 3 and 5, respectively.

The 2 (Group) x 2 (Response) x 3 (Memory-Set Size) analysis of deadline errors for the Search RT tasks showed only two effects. Specifically, main effects of both Memory-Set Size and Response were obtained, i.e., F (2, 56) = 16.22, $p < .001$, and F (1, 28) = 9.62, $p < .005$, respectively. The frequency of deadline errors increased directly as a function of Memory-Set Size (with means of .4, 1.0 and 2.0 for the Memory-Set Sizes of 1, 3 and 5, respectively); and significantly more deadline errors were made with the nondominant hand, i.e., when the stimulus presentation was not one of the critical memory-set items. An average of .80 deadlines occurred per child for the dominant-hand response (i.e., a match between stimulus and memory digit); and an average of 1.42 deadlines occurred per child for non-dominant hand responses (i.e., no match between stimulus and memory digit).

Reaction Latencies

The accurate (i.e., errorless) reaction times for each subject were categorized according to RT task, consecutive blocks of 25 trials, and response type when appropriate (i.e., Dominant vs. Non-dominant response), and then the RT means were calculated. An overall comparison of the Simple RT, Selective RT, and Choice RT tasks was obtained with the factorial of 2 (Groups) x 3 (RT tasks) x 4 (Blocks of 25 trials). For the Choice RT task this analysis included only dominant-hand responses.

This analysis indicated main effects of group, F (1, 28) = 5.04, $p < .05$; task, F (2, 56) = 292.15, $p < .001$; and trial block, F (3, 84) = 5.94, $p < .005$. None of the interactions were reliable, all ps > .05. Overall RT was faster for the Normal than LD children (496 vs. 570 msec.), RT increased directly as a function of task complexity (means of 347, 546 and 707 msec. for Simple, Selective and Choice RT, respectively, and RT increased over consecutive blocks of 25 trials (means of 519, 529, 540 and 545 msec. for the 1st, 2nd, 3rd and 4th trial blocks, respectively.

Insert Figure 1 about here

Figure 1 depicts the mean, dominant-hand RT per group for each of four RT tasks (i.e., the Simple, Selective and Choice RT tasks, and the Search RT task with one digit in the memory set. Although group differences are evident for each task, the RT difference between Normal and LD children increased when the task changed from Simple to Selective RT. In fact, the simple effects test for the Simple RT task indicated no main effect of group, F (1, 28) = 1.62, .25 > p > .10.

Estimates of information processing stages were calculated for each child by subtracting the child's Simple RT mean from Selective RT to indicate Encoding Time, and by subtracting each child's mean Selective RT from mean Choice RT for Decision Time. These estimates for each child are listed in Table 4, which also shows comparisons between the matched Normal and LD children with regard to age, grade in school and scores on ability and achievement tests. This data indicates that the two groups of children are quite equivalent on all factors except

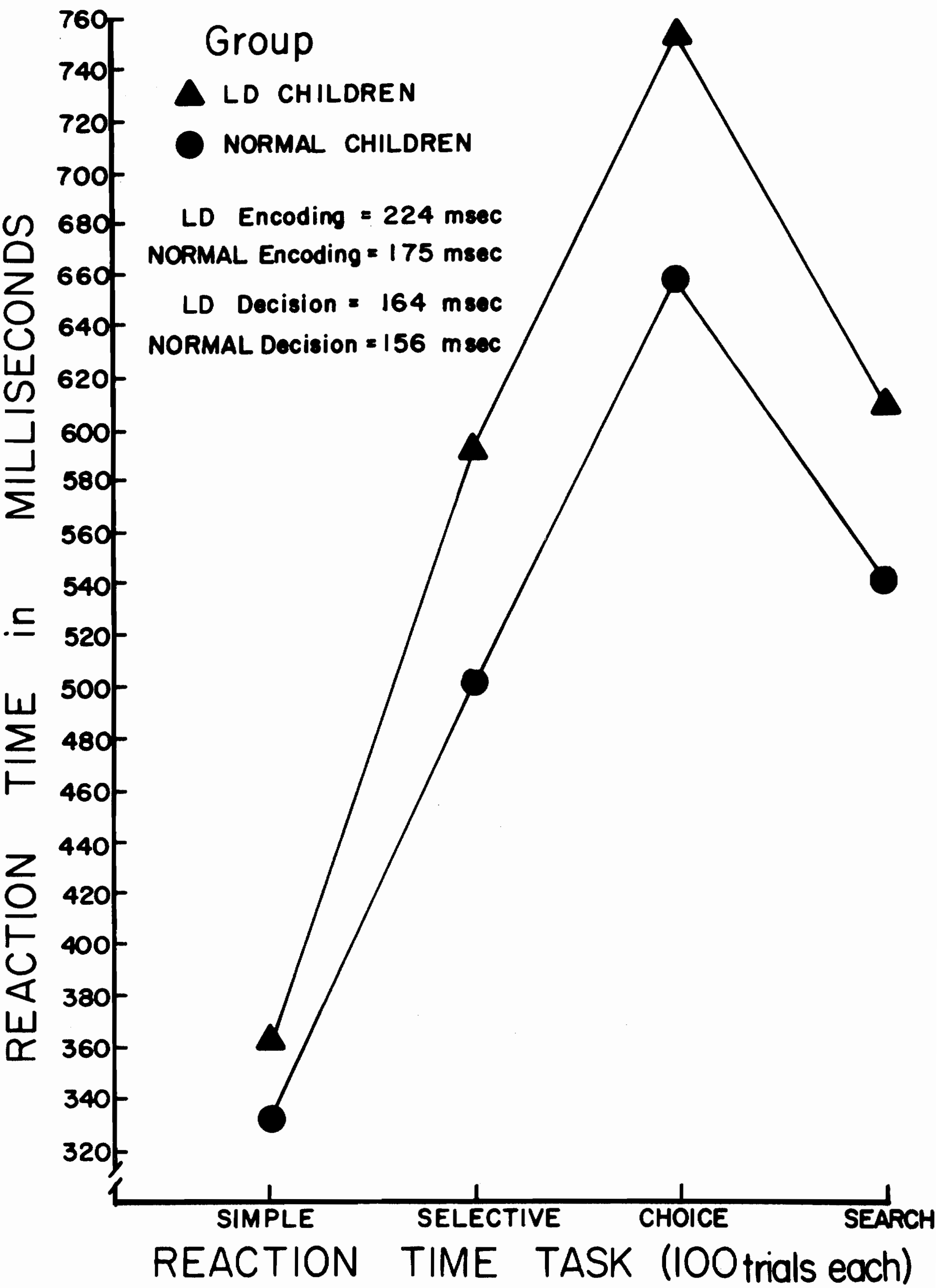

Figure 1. Dominant-hand RT as function of the RT task.

achievement level and encoding time. Specifically, the Normal child performed approximately two grade levels higher than the average LD child, and the mean encoding time of the Normal children was almost 50 msec. faster than that of the LD children.

Insert Table 4 about here

Estimates of encoding and decision time were compared statistically between groups by performing a one-way analysis of variance on each variable. For encoding time (i.e., Selective RT minus Simple RT) there was a significant group effect, F (1, 28) = 6.18, $p < .025$. However, for the estimate of decision time (i.e., Choice RT minus Selective RT) there was no group difference, F (1, 28) = .025, $.25 > p > .50$.

Effects of hand dominance on RT was studied by comparing RT performance between the two tasks with one-to-one mapping between two stimuli and two responses (i.e., Choice RT and Search RT with memory-set size of one item). For each child the mean RT per hand was calculated for the Choice RT and Search RT tasks, and then group means were determined. These means are depicted in Figure 2 and were analyzed according to the factorial of 2 (Groups: LD vs. Normal children) x 2 (Tasks: Choice RT vs. Search RT) x 2 (Responses: Dominant vs. Nondominant response).

Insert Figure 2 about here

The analysis of variance for the data shown in Figure 2 showed main effects of group, F (1, 28) = 6.93, $p < .025$, task, F (1, 28) = 57.33, $p < .001$, and response, F (1, 28) = 23.04, $p < .001$. Further, two

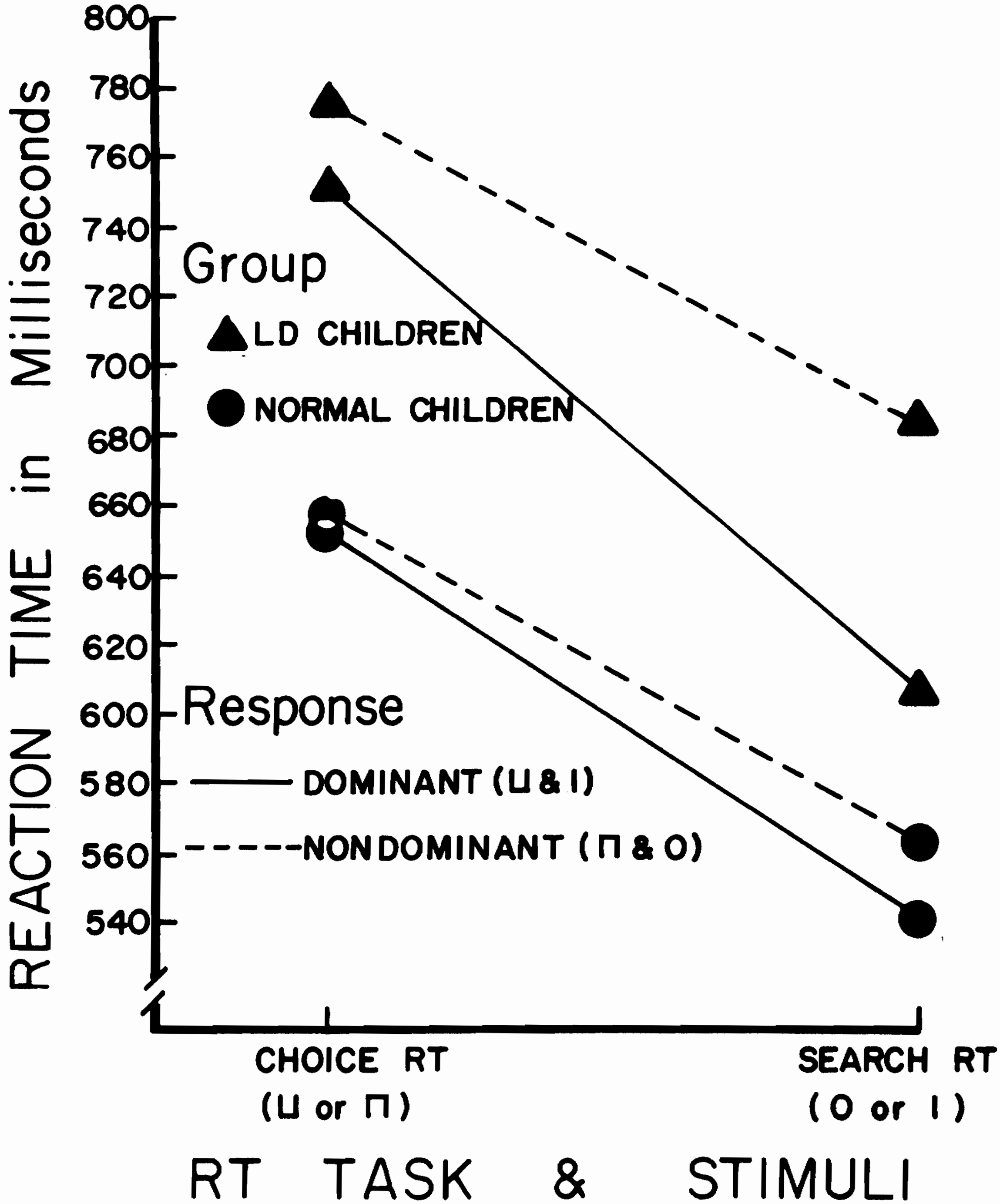

Figure 2. Comparisons between Choice RT and Search RT.

interactions were significant, i.e., Group x Response and Task x Response, respectively, F (1, 28) = 8.01 and F (1, 28) = 13.06, $ps < .01$. The separate analysis of variance for the LD children (using error estimates from the overall analysis) showed main effects of both task and response, respectively, F (1, 28) = 35.49 and F (1, 28) = 47.54, $ps < .001$, and a Task x Response interaction, F (1, 28) = 10.30, $p < .005$. However, the 2 (Task) x 2 (Response) analysis for the Normal group showed a main effect of only task, (F (1, 14) = 23.27, $p < .001$. Neither the main effect of response, nor the Task x Response interaction were reliable, $ps > .10$.

As shown in Figure 2 the mean RTs of both groups were faster for the two-stimulus Search RT task than for the two-stimulus Choice RT task. However, only the LD children showed significantly slower RTs with their nondominant than dominant hand. Also, for the LD group the significant RT difference due to hand dominance was greater for the Search RT task than for the Choice RT task.

The memory-search strategies and memory-search rates were studied for each group of children by categorizing the search RTs of each child according to Memory-Set Size (i.e., the number of digits in the child's critical memory list which was 1, 3 or 5 digits) and the Response Type (i.e., whether the child made a dominant hand-response to indicate a match between the stimulus and a memory-set item or made a nondominant-hand response to indicate that the stimulus was not included among the memory-set items). For each child the mean RT was calculated per each of these categories. Figure 3 depicts the group means for these categories and represents a factorial of 2 (Groups: Normal vs. LD children) x 3 (Memory-Set Sizes: 1, 3 or 5 digits) x 2 (Response Types: Match vs. No-Match).

Insert Figure 3 about here

The analysis of variance for the RT data depicted in Figure 3 indicated main effects of group, F (1, 28) = 4.97, p < .05, memory-set size, F (2, 56) = 248.60, p < .001, and response type, F (1, 38) = 167.09, p < .001. The RTs in this Search RT task were significantly faster for Normal than LD children, for Match rather than No-Match responses, and they increased directly as a function of Memory-Set Size. Two interactions in this analysis were significant; i.e., Memory-Set Size x Response Type, F (2, 56) = 7.75, p < .005, and Group x Memory-Set Size x Response Type, F (2,56) = 6.37, p < .005.

The separate 3 (Memory-Set Size) x 2 (Response Type) analysis for the Normal Group indicated main effects of both memory-set size, F (2, 28) = 121.13, and response type, F (1, 14) = 78.31, and a Memory-Set Size x Response Type interaction F (2, 28) = 14.84, all ps < .001. For the LD group the effects of memory-set size and response type were also significant, F (2, 14) = 130.17, and F (1, 14) = 89.73, respectively (ps < .001), but the interaction was not reliable, F (2, 28) = 2.03, .25 > p > .10.

Insert Figure 4 about here

A step-wise regression analysis was applied to the data depicted in Figure 3 in order to define best-fitting straight lines for RT as a function of memory-set size and to determine the degree of RT variance

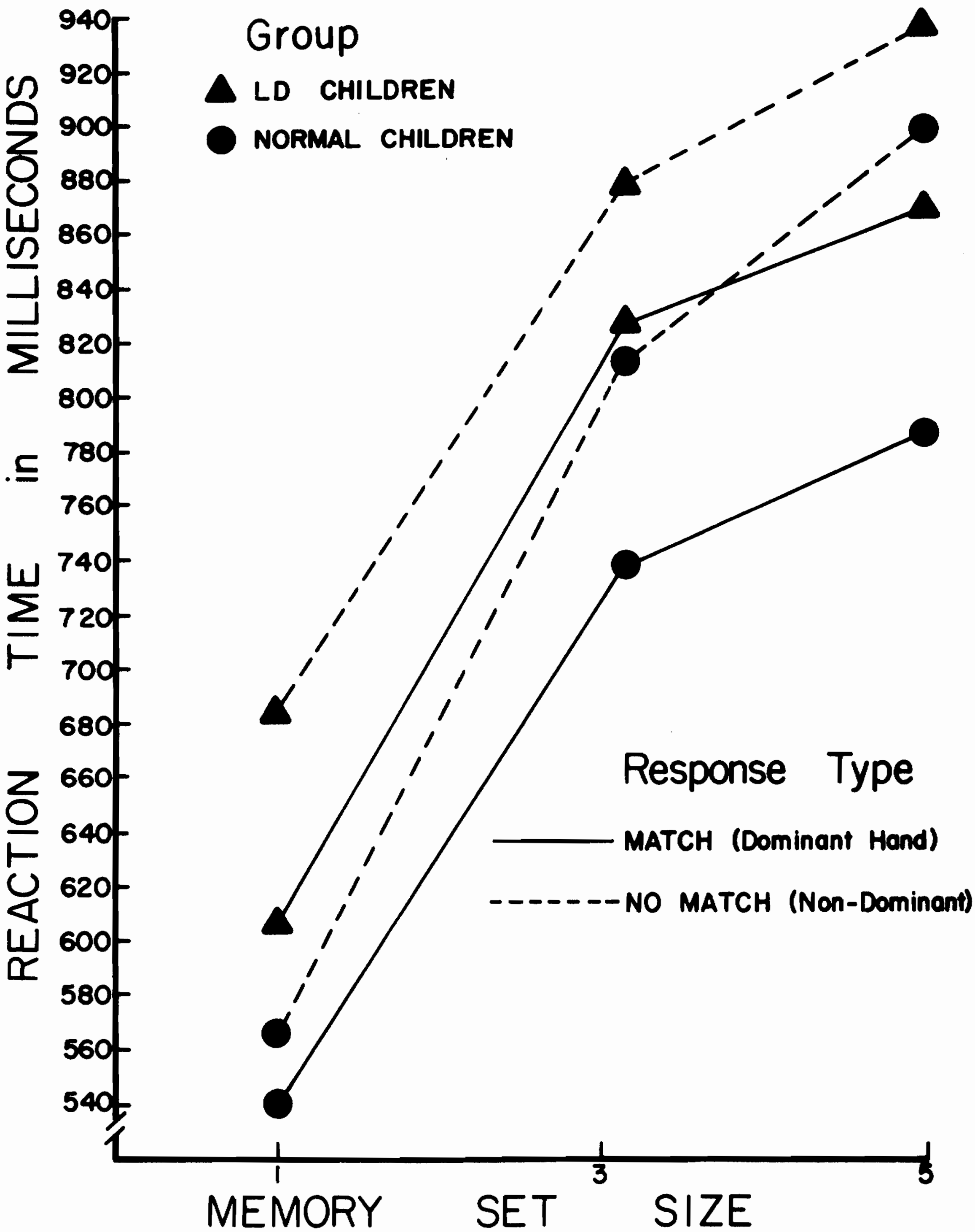

Figure 3. Search RT as a function of Memory-Set Size.

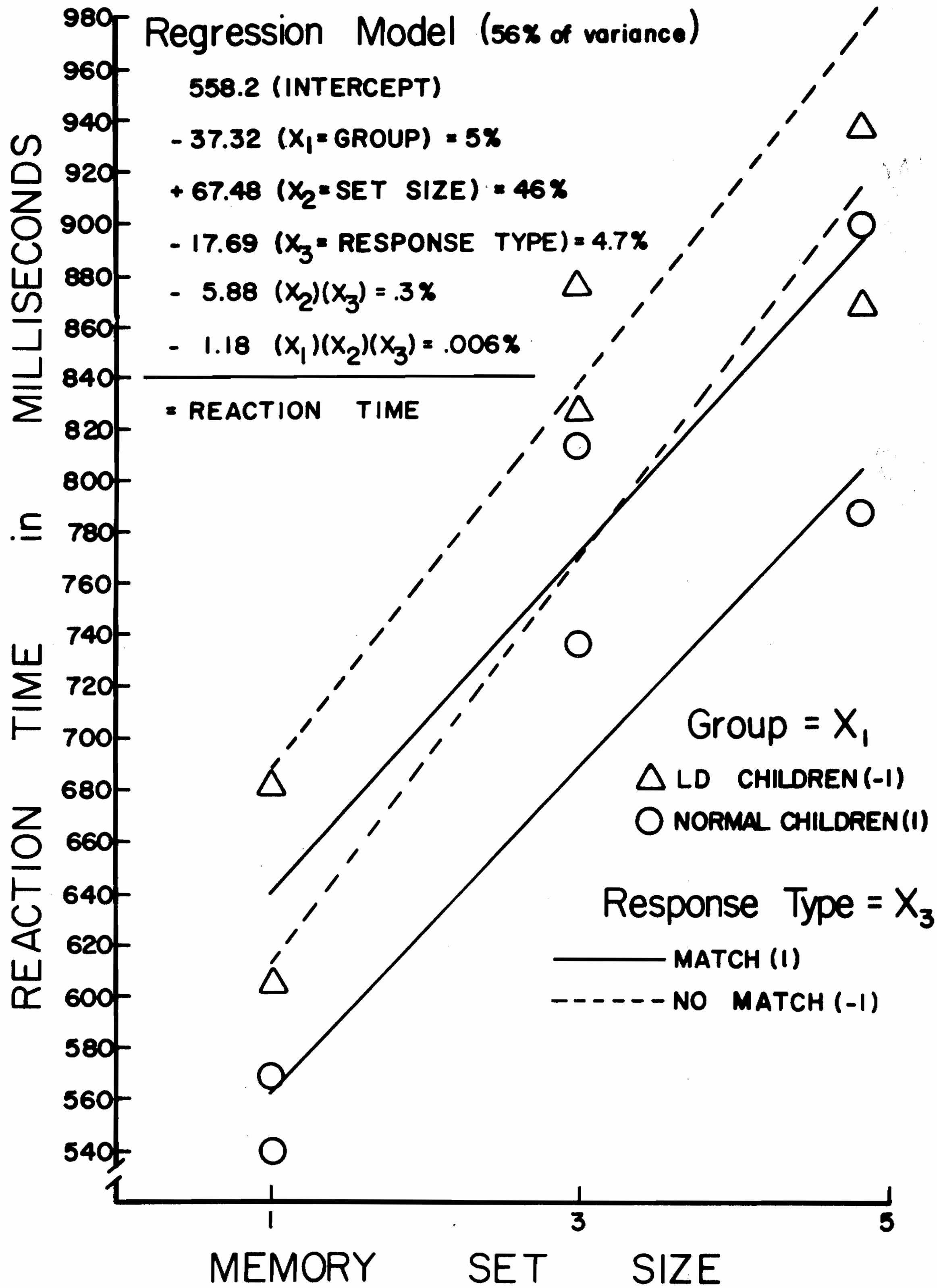

Figure 4. The linear regression model for Search RTs.

accounted for by the independent variables. These straight-line functions are depicted in Figure 4, which also specifies the linear regression model that accounted for 56% of the RT variance. Significant amounts of RT variance were accounted for by the following factors: Group (5%), Memory-Set Size (46%), Response Type (4.7%), Set Size x Response Type (.30%), and Group x Set Size x Response Type (.006%). For the LD group the straight-line functions for each response type are essentially parallel and the slope of these functions is similar to the slope of the function for the Match responses of the Normal children (i.e., about 60 msec.). However, for the Normal group the slope of the function for No-Match responses is steeper than the other RT functions (i.e., about 80 msec.).

CHAPTER V

Discussion

Perhaps the most provocative and interesting outcome of the present research resulted from the group comparisons of Simple, Selective and Choice reaction time (RT) performance. Using the classic subtractive RT methodology introduced by Donders (1889), the group comparisons suggested that stimulus encoding (or stimulus discrimination) was the primary cognitive deficiency of the LD group. That is, the Normal and LD children reacted equivalently fast during the Simple RT task which presumably required stimulus and response execution. However, the LD children responded significantly slower than the Normal children during the Selective RT task (which required a stimulus encoding component not necessary in Simple RT). Furthermore, the group difference for Selective RT did not increase during Choice RT, when a response-decision component was added to the information processing task.

Spring (1971, 1976) compared the latencies of normal and dyslexic children in Choice RT (stimulus-naming) tasks, and found (as in the present study) that children with specific learning disabilities in reading responded reliably slower than the normal children (with no defined learning disabilities). The author actually concluded that the group differences were due to encoding deficits among the dyslexic children. Spring's conclusion was quite risky since between-group differences during Choice RT could be due to deficiencies in any one (or combination of) the information processing components involved in Choice RT; i.e., <u>attending</u> to the stimulus, <u>encoding</u> the stimulus, <u>deciding</u> which response alternative is appropriate, and <u>executing</u> the response. The present application of Donders Subtractive Method offers critical support to the conclusion that stimulus encoding is the stage of information processing most impaired among LD children.

It is noteworthy that a study which compared the Simple RTs of academically-adequate and LD boys found significantly slower RTs by the LD group (Dykman, Walls, Suzuki, Ackerman, & Peters, 1970). In contrast to the present results, these observations imply an attention and/or response execution deficit for the LD children. Such a discrepancy may be accounted for by differential experimenter procedures. That is, the present author used several techniques to maintain the attention and motivation of each subject, which included intermittent rests and performance commendations, and reminders of the prize to be awarded at the end of the two-hour session. The result that no interactions were obtained with consecutive blocks of 25 trials as a factor indicate that the author's systematic "attention-getting" techniques did not confound the results; and also suggests that the present results could have been obtained with a much shorter experimental session (i.e., 25 rather than 100 trials per RT task). This latter ramification holds promise for adopting the present RT procedures as a diagnostic tool for labeling information-processing deficiencies.

The group comparisons between Choice RT and Search RT (with one digit in the memory size) demonstrated critical roles of stimulus familarity and the possibility that the LD children did have a response-related deficiency during information processing (i.e., response selection and/or execution) when reactions with the nondominant hand were considered. First, it is important to realize that the Search RT task with only one item in the positive memory set and one item in the negative set may be easily interpreted by the subject as a Choice RT situation with two stimulus alternatives and two response alternatives. Thus, instead of defining one stimulus-response association with regard to the critical memory-set item and the other association with regard to all other stimuli (as the instructions in the present experiment implied), the subject could define two specific stimulus-response associations, one between the critical item and the dominant hand and the other association between the alternative stimulus and the non-dominant hand. This parsimonious interpretation of the Search RT instructions may have been especially probable in the present experiment since the two-stimulus Choice RT task immediately preceded the Search RT task with one item in the memory set.

Effects of stimulus familarity are suggested by the markedly faster RTs in the Search RT task (with one memory-set item) than in the Choice RT task. Compared with the Choice RT symbols (i.e., |_| and |‾|) the Search RT task involved two relatively familiar stimuli (i.e., the digits 0 and 1). The RTs for both groups of children were prominently facilitated by the use of digits rather than less common symbols, although only the LD children responded slower to the less familiar symbol within the Choice RT task (i.e., slower RTs to |‾| rather than |_|). This finding may reflect more sensitivity to stimulus familiarity by the LD children, but since the more familiar symbol was always matched with the dominant-hand response such group differences may also reflect differential sensitivities to hand dominance. Actually this latter interpretation is more plausible because the change from less familiar symbols to more familiar digits (i.e., from the Choice RT to the Search RT task) facilitated equivalently the RTs of the LD and Normal children.

Although the RT data reflected between-group differences in only stimulus encoding when only dominant-hand responses were considered, the nondominant-hand reactions in the two-stimulus Choice and Search RT tasks suggested response-related deficiencies for the LD children. That is, for both of these tasks only the LD group showed markedly slower response with the nondominant than dominant hand. This difference may have been due to slower response decision and/or response executions for the nondominant than dominant hand of LD children. Followup research could compare Simple RTs between the dominant and nondominant hands of LD and Normal children and thereby estimate the extent that the hand-dominance variable in the present study was due to response-execution deficiency.

The functions relating Search RT to the size of the memory set (i.e., one, three, or five digits) indicated that memory-search rates (estimated from the slopes of these functions) were essentially equivalent for the Normal and LD subjects. The author could find no previous study that compared Search RT between Normal and LD children. However, Search RT experiments have examined age as a factor in Search RT, and, interestingly, most of these studies found no between-group differences in memory-search rate (e.g., Baumeister & Maisto, in press; Hoving, Morin & Konick, 1970; Maisto & Baumeister, 1975; Silverman, 1974). Furthermore, Silverman (1974) observed similar memory-search rates between groups of retarded and normal children (matched on chronological age), and Katz and Wickland (1971, 1973) observed similar visual-search rates between good and poor readers. (Recall that the visual-search task requires the subject to search through a visually-presented list of stimuli for one critical item.)

Most of the memory-search and visual-search experiments that studied age or reading ability as independent variables found intercept differences but no search-rate differences (e.g., Baumeister & Maisto, in press; Hoving et al., 1970; Katz & Wicklund, 1971; Maisto & Baumeister, 1975; Silverman, 1974). The intercept differences in these Search RT studies could have been due to attention, encoding decision, or execution factors (or some combination thereof). The present study showed that Donders' Subtractive RT theory can be successfully applied to determine the relative roles of particular stages of information processing in accounting for intercept differences. Thus, in the present study the Search RT intercepts were significantly higher for the LD than Normal children; and prior comparisons of Simple, Selective and Choice RT suggests that these intercept differences for Search RT were largely due to stimulus-encoding dificiencies among the LD children.

For both groups the intercept of the function relating Search RT to size of memory set were higher for reactions with the nondominant (No Match) than dominant (Match) hand. This difference may, in fact, be due to response selection and/or execution bias associated with hand dominance. However, the lack of hand-dominance effects during Choice RT (for the Normal children) and the significant increase in hand-dominance differences from the Choice to Search RT tasks (for the LD children) implies that no-match decision (i.e., deciding that the stimulus presentation was not included in the critical memory set) required an extra processing stage (cf., Atkinson & Shiffrin, 1968). Perhaps the children re-checked (or searched) the memory list before deciding on a No-Match response.

For the LD children the separate dominant (Match) and nondominant (No Match) functions relating memory-set size to Search RT were essentially parallel (with slopes of approximately 60 milliseconds per memory item). This finding is consistent with those of Sternberg (e.g., 1969), and implies that the LD children followed an exhaustive memory-search strategy rather than a self-terminating process. In other words, the children apparently searched through the entire memory set on each RT trial, regardless of the stimulus presentation. If the children had terminated their memory search as soon as they found (i.e., matched) the critical item, then since the stimulus presentations were equiprobable on the average only half of the memory items would have been searched for the Match (dominant-hand) trials. Therefore, a consistent self-terminating strategy would have resulted in the slope of the linear function for Match responses being one-half the slope of the function for No-Match responses.

For the Normal children the linear function relating Search RT to memory-search size was steeper for identifications of stimuli without the memory set (i.e., No Match, Nondominant-hand responses) than for identification of stimuli within the memory set (i.e., Match, dominant-hand responses). Although the slope of the function for the No-Match RTs was not twice as steep as the slope of the function for Match RTs, the differential slopes do imply that for some presentations of critical, memory-set stimuli the Normal subjects followed a self-terminating strategy. It is noteworthy that such a strategy actually resulted in an overall slower memory-search rate for Normal than LD children. That is, for Normal children the slope of the RT function for Match responses was similar to the slope of the RT functions for both Match and No Match responses of LD children (i.e., approximately 60 millseconds per item); whereas the slope of the RT function for the Normal children's No-Match responses was steeper than the other Search RT functions (i.e., approximately 80 milliseconds per item). Sternberg (1975) claimed that for simple memory search tasks the exhaustive-search strategy is a more parsimonious and efficient process than is a self-terminating strategy. This was apparently the case in the present experiment, and surprisingly the LD children were more likely to adopt the efficient exhaustive-search approach than were the Normal children.

Conclusion

In conclusion, the present study found the dominant-hand RTs of LD children to be significantly slower than those of Normal children during Selective, Choice, and Search RT tasks. The fact that the group RT difference was maximum for the Selective RT task suggests that the major information-processing deficiency of the LD children was stimulus encoding. However, some response selection and/or response execution deficiencies were suggested for the LD group when RTs with nondominant hands were considered. That is, only the LD children showed markedly slower reactions with their nondominant than dominant hands during the Choice RT and two-choice, Search RT tasks. Followup research could apply Donders Subtractive Method to determine the degree to which response execution and response selection contribute to this dominance bias for

LD children. Followup studies should also be designed to compare the memory search strategies of LD and Normal children. As expected the average memory-search rate of the LD children in the present study was not slower than that of the Normal children; but unexpectedly the LD children were more apt to follow-up the more efficient (and less complex) search strategy than were the Normal children (i.e., exhaustive rather than self-terminating search).

The absence of any interactions with a 25-trial-block factor indicates that the two-hour experimental sessions were almost four times longer than they needed to be, and therefore followup research could examine larger numbers of subjects in less time. Indeed, Donders' Subtractive Method could be applied within 30 minutes, and perhaps serve as a valuable diagnostic tool for specifying particular information-processing dysfunctions of LD children. Moreover, since RT performance is not biased by practice (i.e., learning), Donders' Subtractive Method may eventually prove to be a useful indication of cognitive effects due to special remediation programs.

Thus, the present application of Donders' Subtractive Model added substantially to the previous research that attempted to compare cognitive processing between normal and abnormal children by studying reaction times. Prior RT studies have demonstrated intercept differences between normal and abnormal groups, but the present investigation pinpointed the particular cognitive dysfunction (i.e., stimulus encoding) that was largely responsible for Normal children responding significantly faster than LD children in Choice RT and Search RT tasks. Normal and LD children did not show reliable differences at accomplishing other components of information processing; i.e., attending to the stimulus, searching serially through memory for a critical digit, deciding which response is appropriate, or executing the appropriate response. The finding that the between-group differences in RT did not interact with consecutive blocks of 25 trials suggests that relatively short RT sessions may be used to obtain estimates of the duration of certain cognitive functions. The possibility that short, RT sessions can serve to aid the diagnosis of particular cognitive deficiencies or to demonstrate particular cognitive facilitation after special remediation is certainly provocative. The present study may indeed be a successive approximation toward reaching such a worthwhile target, but much follow-up research is definitely needed. Hopefully, the present study will prompt the accomplishment of further approximations toward understanding the particular cognitive dysfunctioning of LD children.

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APPENDIX A

Sullivan/Sherman; Revised, 1973

BEHAVIOR CHECKLIST

Instructions: Place one check mark in the margin opposite those items which are representation of this child's typical behavior. Use two check marks for those items which he shows more frequently. Use three check marks if the behavior item is most outstanding by its frequency.

N.B. The rater should be very familiar with the child's classroom behavior over a period of time. Take the average child in a regular classroom as your basis for comparison.

Name________________________Sex____Grade____Date______Teacher________

____1. Is very sensitive to criticism

____2. Expresses feelings of inadequacy about self

____3. Does not make self known to others

____4. Is aggressive in underhanded ways

____5. Seeks attention excessively

____6. Has very short attention span

____7. Does not work independently

____8. Shows signs of nervousness (nailbiting, crying, tics, rocking)

____9. Daydreams or shows excessive fantasy preoccupation

____10. Shows poor gross and/or fine motor coordination; has difficulty handling working materials such as crayons, pencil, scissors, awkward or clumsy

____11. Does not follow rules; does not take turns

____12. Is very messy with work or belongings

____13. Is negativistic: "I won't"

____14. Is considered an isolate in class; plays alone, avoids group activities

____15. Displays infantile behavior (crawling, whining, clinging, chewing)

____16. Makes irrelevant or inappropriate remarks or odd noises

____17. Misinterprets simple statements

____18. Seems disoriented to surroundings, and/or confused as to directions given

____19. Displays antisocial tendencies (destructive, hostile, temper tantrums, steaks, lies, defies, deeply resents discipline)

____20. Tends to become inactive, uninvolved in free situations

____21. Seems tired or ill, frequently absent (from real or "fake" ills)

____22. Shows evidence of underachievement in academic areas in relation to ability

APPENDIX B

Instructions for Simple Reaction Time

This is an experiment to see how fast you can pull a trigger after seeing a symbol. I want you to pull this trigger (position child's hand) as quickly as you can as soon as you see this square symbol light up on the board (present stimulus). First you will hear a buzzer that will tell you the symbol will be lighting up soon. The buzzer is a signal for you to get ready to pull the trigger. All you have to do, then, is to pull the trigger as soon as you see the square.

Please try not to pull the trigger before the square appears. If you do pull the trigger too early, you will hear a special buzzer and we will have to do the trial over. Also if you pull the trigger too slowly the error buzzer will go off, so pull the buzzer as fast as you can. Now tell me what you will do for this task. We will have 10 chances ot practice before we actually begin. If you have any questions, please ask me during the practice trials. (Give one-min. break after 50 trials and a three-min. break after 100 trials.)

Instructions for Selective Reaction Time

This time, instead of the square, there will be two different symbols which may light up after you hear the buzzer. I only want you to pull the trigger if you see this symbol, (present stimulus), which looks like the letter "C". Remember to pull the trigger as quickly as you can when you see this symbol. If the symbol points the other way, like a backwards "C" (present stimulus), then do not pull the trigger at all.

If you pull the trigger before a symbol lights up, or if you pull it when you are not supposed to, you will hear the buzzer and we must re-do the trial. This buzzer will also go off if you pull the trigger too slowly, so pull the correct trigger as fast as you can. Now tell me what you are going to do. Now we will have some practice trials during which you may ask me any questions. Remember to pull the trigger only to the letter "C". (Give a one-min. break after 50 trials and a three-min. break after 100 trials.)

Instructions for Choice Reaction Time

This last part is a little more difficult. There will be two different kinds of symbols but this time they will either point up like the letter "U", or point down like and upside down "U", (present stimulus). As before, a buzzer will tell you that a symbol is about to light up. When the "U" shaped symbol appears, pull the right (point) trigger as quickly as you can. Again, if you hear a buzzer it means that you pulled the trigger before the symbol appeared or that you pulled an incorrect trigger. If you respond too slowly the error buzzer will sound, so identify the symbols as quickly as you can. Now, can you tell me what you are going to do this time? (Be sure child understands the contingencies.) You will have 10 chances to practice. (Give a one-min. break after 50 trials and a ten-min. break after completion of this task.)

Instructions for Memory Set Size 1

For this experiment, I want to see how well you can remember numbers in your head. I will show you some numbers that I want you to remember. These will be called the "special" numbers. Then after you hear the buzzer, a number will light up on the board. If the number on the board is one of the special numbers you were asked to remember, then pull the (right or left: dominant) trigger (point) as quickly as you can. If the number on the board is not a special number, then pull the (nondominant) trigger as quickly as you can. If you hear a buzzer it means that you pulled a trigger before a number appeared, or that you pulled an incorrect trigger, or that you were too slow in pulling the trigger.

For now the "special" number I want you to remember is the number "1" (place card in front of child). If the number "1" lights up which trigger will you pull? (Correct child if wrong, or if correct, say "That's right because '1' is the special number".) Now we are going to practice a few times before we begin so we can discuss any questions that may come up. (Give 10 practice trials, and a one-min. break after 50 trials and a three-min. break after 100 trials.)

Instructions for Memory Set Size 3

Now we are going to do the same thing but the special numbers for you to remember this time are 0, 2, and 5 (place card). If a 0, a 2, or a 5 lights up you are to pull the (dominant) trigger as quickly as you can. If any other number lights up, quickly pull the (nondominant) trigger. Now what will you do this time? As usual we will have 10 practice trials. (Give a one-min. break after 50 trials and a three-min. break after 100 trials.)

Instructions for Memory Set Size 5

This will be the last set of numbers I will ask you to remember. The special numbers this time are 1, 3, 6, 8, and 9 (place card). If a 1, a 3, a 6, an 8, or a 9 lights up, pull the (dominant) trigger as quickly as you can. If any other number lights up, quickly pull the (nondominant) trigger. Now what will you do this time? You will have 10 chances to practice. (Give a one-min. break after 50 trials.)

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Date of Birth:	March 13, 1943
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Marital Status:	Married; Husbands name, Scott
Maiden Name:	Hillis
Husband's Employment:	Associate Professor, Psychology Department, Virginia Polytechnic Institute & State Univ.

Education:

Degree	Year	Area	Institution & Location
B.S.	June, 1967	Special Education	Southern Illinois Univ. Carbondale, Illinois
M.S.	August, 1969	Special Education	Southern Illinois Univ. Carbondale, Illinois
Certification School Psych.	March, 1972	School Psychology	Radford College, Radford, Virginia
Doctoral Student	Sept., 1972 to June, 1978	Superv. & Adm.	Virginia Polytechnic Institute and State Univ., Blacksburg, Va.

Professional Experience:

Teaching

September, 1967-June, 1968	Teaching a primary Educable Mentally Handicapped class at the Lake Bluff West School in Lake Bluff, Illinois

Educational Consultant

September, 1969-August, 1971

Coordinated a team of professionals (School Psychologist, Social Worker and Speech Therapist) in the counties of Floyd and Montgomery for a Title III, ESEA grant, Project Helping Hand.

School Psychologist - Montgomery County

September, 1971-June, 1973

Duties Involved:
a. Individual testing and assessment for special education placement.
b. Acting Chairman of the Montgomery County Schools Placement Committee.
c. Coordination and supervision of the Learning Disability Program.
d. Supervision of practicum students in the Department of School Psychology, Radford College.
e. Workshops for teachers in the areas of Learning Disabilities and Behavioral Management.

Adjunct Professor - VPI&SU

September, 1973-December, 1973

Courses Included:
a. Diagnosis and Remediation of Reading Problems
b. Exceptional Children

Technical Assistant

January, 1974-June, 1974

Duties Involved:
a. Mediated the activities between the VPI&SU education department and Montgomery County School personnel.
b. Helped to supervise the on-the-job training of the LD teachers enrolled in the VPI&SU LD program.
c. Assisted in implementing the behavior objectives of the Multi-Level Training Program designed by Dr. Houck.
d. Refined a tape slide series that presents a working LD program.
e. Assisted in the development and presentation of workshops that taught the basic objectives of a community multi-level LD training program.

Instructor of Special Education - Radford College

September, 1974 to present

Duties Involved:

1. Teaching the following special eduation courses:
   a. Survey of Exceptional Children
   b. Characteristics of the Mentally Retarded
   c. Evaluative Techniques
   d. Introduction to Learning Disabilities
   e. Teaching Children with Learning Disabilities
   f. Diagnosis of Learning Problems
2. Supervising student teachers:
   a. Undergraduate education and special education majors.
   b. Graduate LD students.

Professional Presentations:

April 1972 - Southwestern Psychological Association, Atlanta, Georgia. Workshop presented on "Behavior Modification in the Schools and Community". (Presented with Dr. Scott Geller, VPI&SU.)

Nov. 1972 - Virginia Psychological Association and Virginia Association for School Psychologists, Blacksburg, Va. "Learning Disabilities: Educational Implications, Intervention Procedures and Instructional Materials". (Presented with Dr. Cherry Houck, VPI&SU.)

Sept. 1977 - Participated in VPI&SU's project (#451-AH70579) in preparing a handbook and videotape on the needs of handicapped children.

Professional Societies:

Council for Exceptional Children (CEC)
Virginia Association for School Psychologist (VASP)
Virginia Association for Learning Disabilities (VCLD)

Community and Professional Activities:

Member of the Board of Directors of the Blacksburg Mental Health Association (1972-1973)
Member of the Board of Directors of the Big Brother, Big Sister Organization (1972-1974)
Member of the Board of Directors of the Raft, Inc. - Drug Education and Crisis Intervention Center (1973)
Member of the Montgomery-Giles Association for Children with Learning Disabilities (1977-1978)

Carol H. Geller

THE USE OF REACTION TIME TO ASSESS COGNITIVE

FUNCTIONING OF LEARNING DISABLED CHILDREN

by

Carol H. Geller

(ABSTRACT)

Fifteen children (mean age 10 years) who were defined as learning disabled (LD) by school authorities and were enrolled in special LD classrooms were matched with 15 children from regular school classrooms on the basis of sex, chronological age, and mental age. Each child performed individually in a two-hour reaction time (RT) session, during which four different RT tasks were administered. All children received the following tasks, ordered as listed: Simple RT (100 trials), Selective RT (100 trials), Choice RT (100 trials), and Search RT (100 trials with one digit in the memory set, 100 trials with memory-set size of 3, and 100 trials of memory-set size of 5). For Simple RT, subjects pulled a reaction trigger with their dominant hand following the symbol |‾_|; for Selective RT, the symbol |‾_ or ‾_| was presented and subjects pulled the dominant-hand trigger to |‾_; and for Choice RT, subjects pulled the dominant-hand trigger to |_| and the nondominant-hand trigger to |‾|. Prior to each block of 100 trials during the Search RT task certain digits were defined as critical memory-set items (i.e., 1 for Set-Size 1; 0, 2 and 5 for Set-Size 3; and 1, 3, 6, 8 and 9 for Set-Size 5); and the child was requested to pull the dominant-hand trigger if the stimulus presentation was included in the memory set and to pull the nondominant-hand trigger for stimuli not included in the memory set. For each task the stimulus presentation was preceded by a "ready" buzzer and then a random interval ranging from .5 to 1.5 sec.

The RTs were equivalent between groups for the Simple RT task, but were significantly slower for the LD children during the Selective, Choice, and Search RT tasks. The between-group, RT difference was maximum for the Selective RT task, and therefore an application of Donders' Subtractive Model reflected that stimulus encoding was the only cognitive dysfunction among the LD children. Furthermore, the functions relating Search RT to Memory-Set Size demonstrated equivalent memory search rates for the normal and LD children. Such findings suggest that RT may be used to diagnose particular cognitive deficiencies or to demonstrate particular facilitative effects of cognitive-remediation programs. The finding that consecutive blocks of 25 trials did not interact with the latencies in any RT task, suggests that individual sessions to obtain diagnostic RT can be as short as 15 minutes (i.e., 25 trials per RT task). The present RT results are discussed with reference to other RT studies that compared reaction latencies between normal and abnormal subjects.