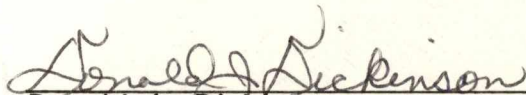
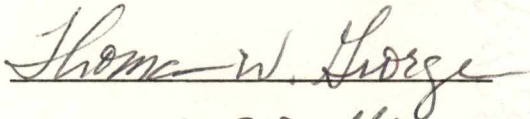


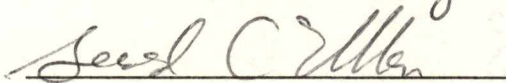
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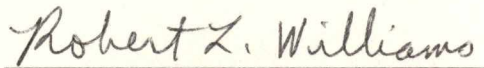
I am submitting herewith a dissertation written by J. Michael Carrig entitled "Sequential and Simultaneous Processing and Reading Performance in the First Grade." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Education.

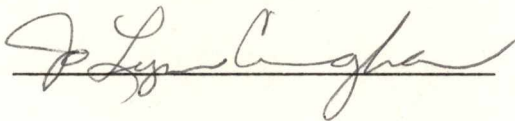

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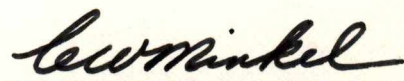








Accepted for the Council:


Vice Provost
and Dean of The Graduate School

SEQUENTIAL AND SIMULTANEOUS PROCESSING AND READING
PERFORMANCE IN THE FIRST GRADE

A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville

J. Michael Carrig

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ABSTRACT

The purpose of this study was to relate the acquisition of reading skills by first-grade students to assessed sequential and simultaneous cognitive processing abilities. Eighty-six students from five first-grade classrooms at Alcoa Elementary School, Alcoa, Tennessee, were selected as subjects.

An ex post facto research design was used to test 11 hypotheses. Psychometric data were obtained from fall and spring administrations of the California Achievement Tests--Reading subtests and fall testing on the mental processing scales of the Kaufman Assessment Battery for Children. Classroom achievement levels (groups) were determined by obtaining, in interviews with the first-grade teachers, information on student mastery of reading objectives and performance in the classroom.

In general, the results of the research indicated that sequential- and simultaneous-processing abilities are significant factors in accounting for the variability in first-grade students' reading performance. Both factors were found to be involved equally in the reading process, but they did not differ in their relationship to reading skill acquisition. It was also indicated that a discrepancy between sequential- and simultaneous-processing abilities existed with students at all classroom performance levels (i.e., Levels 1, 2, 3, 4). The students with assessed sequential- and simultaneous-processing abilities at a high or low level also achieved a corresponding high or low level of performance in the classroom. The prediction of spring

CAT reading subtest scores was found to be as accurate with fall sequential and simultaneous measures as with the fall CAT reading test scores. End-of-the-year placement in achievement groups, based on classroom performance on the reading curriculum, was predicted equally well by fall CAT total reading scores and the K-ABC mental processing factor scores.

Measures of sequential and simultaneous processing are useful in the development of an understanding of the underlying cognitive processes involved in reading. Results of the research also have implications for use of cognitive processing measures with beginning readers in the prediction of reading development. The early identification of children's needs can affect how the initial reading experience is shaped via the curriculum and instructional processes.

Although this investigation confirms the significance of information processing skills' relationship to the reading process, researchers must continue to explore the differential effects of these factors on reading subskills. This is important if a causal relationship is to be hypothesized and psychometric measures of intelligence are to advance beyond their present use in predicting future achievement in school.

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CHAPTER I

INTRODUCTION

Measures of intelligence and cognitive functioning have traditionally been important to education because they have provided a means by which educators could predict student performance and inform educational practice. Ironically, although intelligence tests are widely used, the construct of intelligence has not proved to be particularly useful in providing relevant information on handling student differences in task performance. The need to link cognitive and intelligence test data to task performance is rooted in early research on individual differences. In addition, current federal and state requirements for individualized educational programs (IEPs) for the handicapped and intensive efforts nationwide on assuring minimum competency levels for students in basic skills have placed a greater emphasis on the need to develop assessment-intervention links.

Aptitude-Treatment Interaction

As a profession, school psychology has attempted to develop a systematic means of using intelligence and cognitive test data to help in the planning of educational interventions. Credit for providing the early impetus to this effort is often given to Cronbach (1957). Cronbach urged an effort be made to observe the effects of different measured cognitive variables on student performance and to conduct experimental investigations designed to validate aptitude-treatment interactions. The aptitude-treatment interaction (ATI) design appears

to offer a sound theoretical base from which to establish an empirical link between assessed aptitude and optimum instructional intervention. However, to date, investigations using an ATI design have not provided support to intelligence or cognitive assessment-intervention links. Reviews of research by Bracht (1970) and Ysseldyke (1973) failed to produce evidence of significant ATI interactions. Neither was there a relationship between aptitude (i.e., intellectual and cognitive skills) and prescriptive teaching in subsequent studies by Newcomer and Goodman (1975); Vandever and Neville (1974); Sabatino, Ysseldyke, and Woolston (1973); and Ysseldyke (1977).

The dissatisfaction with early ATI studies led cognitive theorists to consider two alternative positions from which the ATI puzzle might be better investigated. The first position involves the investigation of learner control in instruction. Learner control refers to the ability of the student to recognize his/her strengths and weaknesses in learning and to focus on the strengths in developing an appropriate learning style or method. The second position involves the need to investigate the underlying information processes common to performance on aptitude tests and classroom settings (Wagner & Sternberg, 1984, p. 192). Both alternative positions address what are believed to be methodological problems in the ATI studies mentioned.

The first position represents the rejection of the deficit-centered cognitive-remediation models (e.g., Illinois Test of Psycholinguistic Abilities (ITPA) psycholinguistic model) that dominated earlier ATI studies. The deficit-centered models are designed for use in assessing

the weaknesses of the student and subsequently to help in developing strategies to remediate those weaknesses. Emphasis is now on the strength models of remediation that Reynolds (1981) described as

based on the processes that are sufficiently intact so as to subserve the successful accomplishment of steps in the educational program, so that the interface between cognitive strengths . . . determined from the assessment and the intervention strategy is the cornerstone of meaningfulness for the entire diagnostic-intervention process. (p. 344)

A strengths model of remediation relies on the identification of functional systems in the brain that can control and moderate the learning process necessary to master the learning tasks required. It should be noted that, unlike most deficit-centered models, a strengths model does not dictate what is to be taught. What to teach a student comes from task analysis and diagnostic-achievement testing. These measures identify the problems that the student is having with specific skills. A strengths model of remediation helps educators to determine how to teach. The assessment of the student should provide direction to the teacher in how the learning material should be organized and presented to promote learning (Reynolds, 1986, p. 258).

A strengths-remediation model with its emphasis on mental processing skills relates directly to the second alternative position that promotes the investigation of the assessment of underlying information processes common to performances on aptitude tests and classroom learning tasks. This position is, in part, a response to the fact that the current instruments primarily used for measuring intelligence and cognitive skills (e.g., Wechsler Intelligence Scale for Children--Revised [WISC-R], Stanford-Binet) have been developed

primarily on an empirical basis, not from a theoretical construct of intelligence (Reynolds, Gutkin, Elliott, & Witt, 1984, p. 138). Although empiricism is an important aspect of test development, it is not considered sufficient in itself for testing a theoretical construct such as intelligence. There appears to be, as a result of this, a large gap between the processes measured on aptitude or IQ tests and the processes required for school learning.

Information Processing and Achievement

A new perspective on intellectual functioning came to prominence with the work of Luria (1966a, 1966b, 1973). In his clinical investigations of brain-injured clients, Luria established the fact that intellectual functions could be based on cortical and subcortical structures of the brain. The neuropsychological view of brain functioning presented by Luria emphasized that in higher cortical functions of the brain, problem solving and the integration of sensory material are conducted by the coding of simultaneous and successive information. An elaboration of Luria's work by Das, Kirby, and Jarman (1975, 1979) demonstrated that a model of information-processing based on simultaneous and successive (i.e., sequential) coding skills could be applied to investigating the relationship between assessed intellectual functioning and children's school achievement. Cognitive theorists do not expect measures of intellectual functioning based on information processing theory to correlate more highly with achievement than do traditional measures of intelligence. However, the

advantage of measuring intellectual functioning based on information-processing theory is that it provides a rational basis for decomposing task performance in achievement into underlying mental processes. Once the task performance is isolated into components, educational objectives can be developed that are consistent with the learner's identified information-processing abilities (Wagner & Sternberg, 1984).

Statement of Purpose

There is a significant gap between cognitive psychology and educational practice as promoted in the public schools. The information-processing model of intelligence appears to offer a means by which the theoretical underlying processes of intellect can be empirically related to task performance in the classroom. How much improvement an information-processing model, focused on sequential and simultaneous coding abilities, is over alternative approaches to integrating intelligence with school achievement is difficult to ascertain at this point. Undoubtedly, success in using the model in predicting learning depends on the confirmation of the degree of variability in learning specific skills that can be attributed to the assessed processing skills of the student. Although some research has been done to establish a relationship between various processing skills and achievement, there is a paucity of evidence that supports the theory that measures of cognitive-information-processing account for a significant variability in how normal children learn basic skills in their first years of school.

The acquisition and refinement of reading skills is a primary focus of elementary education. Reading is a very complex process that requires the use of many cognitive abilities and learning skills. Difficulties by students in the development of reading skills provide a majority of the referral problems encountered by school psychologists. The assessment of reading difficulties generally involves an analysis of cognitive abilities that are assumed to be reflective of underlying processes related to the learning of reading tasks. If Luria (1966a) and Das, Kirby, and Jarman (1979) are correct in their theoretical assertions on cognitive information processing, then the sequential- and simultaneous-processing abilities of each child would be significantly related to the acquisition and development of reading skills.

Purpose

This current investigation was conducted for the purpose of studying an information-processing model of intellectual functioning and how it may be used to contribute to the aptitude-treatment interaction designs. The focus of this investigation was on relating the acquisition of reading skills to assessed information-processing abilities of first-grade students.

Conceptual Definitions of Variables

In the current investigation, two types of information processing were included. Conceptually, the terms sequential or successive

processing refer to the cognitive activity of the brain by which encoded information is processed in a serial order. In problem solving, sequential or successive processing involves the consecutive ordering of components of information by the brain in order to arrive at a solution. Successive processing is the term used in earlier research reported by Luria (1973), Das et al. (1975, 1979), and their colleagues. The term sequential processing was used in reported research by Kaufman and Kaufman (1983a, 1983b) and related research by other authors. The second information-processing variable is referred to as simultaneous processing. Simultaneous processing is defined as the cognitive activity of the brain by which separate elements of information are coded and organized into groups. In problem solving, simultaneous processing involves the integration of selected components of information at the same time in order to arrive at a solution.

Three types of reading skills were included. Phonic analysis is a term defined as a subskill of reading by which sounds (phonemes) or oral language are related to graphic symbols (graphemes) of written language. Reading vocabulary is defined as the ability to understand sight words through use of synonyms, antonyms, and multimeaning words. Reading comprehension refers to the ability to derive literal and interpretive meaning from reading material.

Assumptions

The current investigation was conducted based on two major assumptions:

1. The learning of reading skills is of primary importance in the schooling process. Therefore, the assessment and evaluation of factors involved in reading-skill development are goals for educators to achieve.

2. The assessment of cognitive and reading skills using specialists (e.g., school psychologists) is a practical and useful way to assess student performance. In turn, the assessment of student performance using this delivery model can be used in the schools to investigate the relationship between cognitive abilities and students' reading skills.

CHAPTER II

REVIEW OF THE LITERATURE

Research that provides a foundation from which to address the relationship between cognitive processing abilities and reading performance is found in several different areas of study. It is only in the past two decades that the findings from various investigations in cognition, psychometrics, and reading have been brought together to help provide a better understanding of the information processing-reading connection.

This chapter includes a review of recent investigations that trace the development of the simultaneous- and sequential-processing model and how aspects of this model have been used in the creation of models of reading-skill development. Psychometrics will also be addressed in terms of studies in which normative intelligence and cognitive instruments have been used to measure sequential and simultaneous factors. How these measured factors have been related to achievement measures, including reading, will be reviewed.

Simultaneous and Successive Cognitive
Processing

Beginning in the mid-19th century, a considerable body of research has been accumulated that supports the idea that the human brain has two hemispheres that serve specialized functions. Early evidence for this functional asymmetry of the brain was gathered using observations of brain-injured patients (e.g., Jackson, 1874/1932).

Jackson concluded from these clinical observations that the left hemisphere of the brain appeared to be primarily involved in expression (language) and the right hemisphere served thinking through sensation and perception (Dean, 1984, p. 240). It was not until the mid-20th century, after research on localized functions in distinct areas of the brain waned, that hemispheric specialization was elaborated on including a more global and control function for the dominant (language) hemisphere. Research on hemispheric specialization moved from using clinical observation to the use of inferential methods based on test data. Inferences were made from a battery of tests administered to patients with various localized brain lesions.

Reitan (1955), using this approach, established that damage to the left hemisphere of the brain corresponded to functional impairment in language, speech, and math calculation. He found that lesions to the right hemisphere corresponded to functional deficits in nonverbal reasoning and problem solving. The research of Sperry and his associates (Gazzaniga & Sperry, 1962; Sperry, 1968, 1969; Sperry, Gazzaniga, & Bogen, 1969) further added to the understanding of brain hemispheric functioning. Sperry and his associates researched functional lateralization with patients who had surgical removal of the corpus collusum as a treatment for intractable seizures. This procedure reduced the amount of interhemisphere information that could be transferred and allowed for a better isolation of the left and right hemispheric function. The result of this research provides

supporting evidence that cognitive processes of the two hemispheres differ in basic strategy. The left and right halves of the human brain have different modes of performance. Research with split-brained patients has confirmed that in most right-handed people and in many left-handed people, complex language functions are addressed by the left hemisphere. In turn, right hemisphere activity is linked to visual-spatial functions.

The recognition of the brain having functional specialization was approached by Luria (1966a, 1966b, 1970) using a concept of information coding and planning. Luria reported research from clinical testing of clients with cerebral lesions. Using clinical tests developed by several researchers, Luria studied the different levels of simultaneous and successive syntheses in patients. His analyses of the data revealed that there were profound differences in higher cortical processes between patients. The differences were revealed primarily by the fact that patients with lesions in the posterior regions of the brain had diminished ability to integrate individual visual or tactile stimuli into simultaneous and, in particular, spatially organized groups. In contrast, patients with lesions in the anterior regions of the brain experienced dysfunction in their ability to integrate individual motor and auditory stimuli into successive, serially organized groups (Luria, 1966b, p. 125).

Luria's study of the effects of lesions on different parts of the brain not only revealed dysfunctions in the two forms of integrative activity (i.e., successive and simultaneous syntheses) but also

different forms of dysfunction in these syntheses. It was supported by his data that disturbances in syntheses took place at the sensorimotor, memory, and complex (symbolic) levels of brain functioning. Luria viewed this development of a neuropsychological model of brain functioning as the first step in the investigation of the role of simultaneous and successive syntheses in the development of intellectual ability.

Attempting to conceptualize intellectual functioning in terms of his systems approach to the working brain, Luria (1973) developed a model of mental operations (see Figure 1) in which brain functioning was explained by dividing it into three units or blocks of activity. In this context, mental activity depends upon the dynamic nature of interaction among the three units. Luria (1973) described the units as "a unit for regulating tone or working, a unit for obtaining, processing and storing information . . . and a unit for programming, regulating and verifying mental activity" (p. 43). In addition, each unit has three cortical zones that control the function of each unit. These zones are divided into primary areas, secondary areas, and tertiary areas of complex mental activity.

Das et al. (1975, 1979) elaborated on the work of Luria using factor-analytic techniques rather than symptomatic investigations to provide support for the simultaneous-successive theory of brain activity. Das et al. (1979), in their speculation about the relationship among Luria's three functional units of the brain and intelligence, stated:

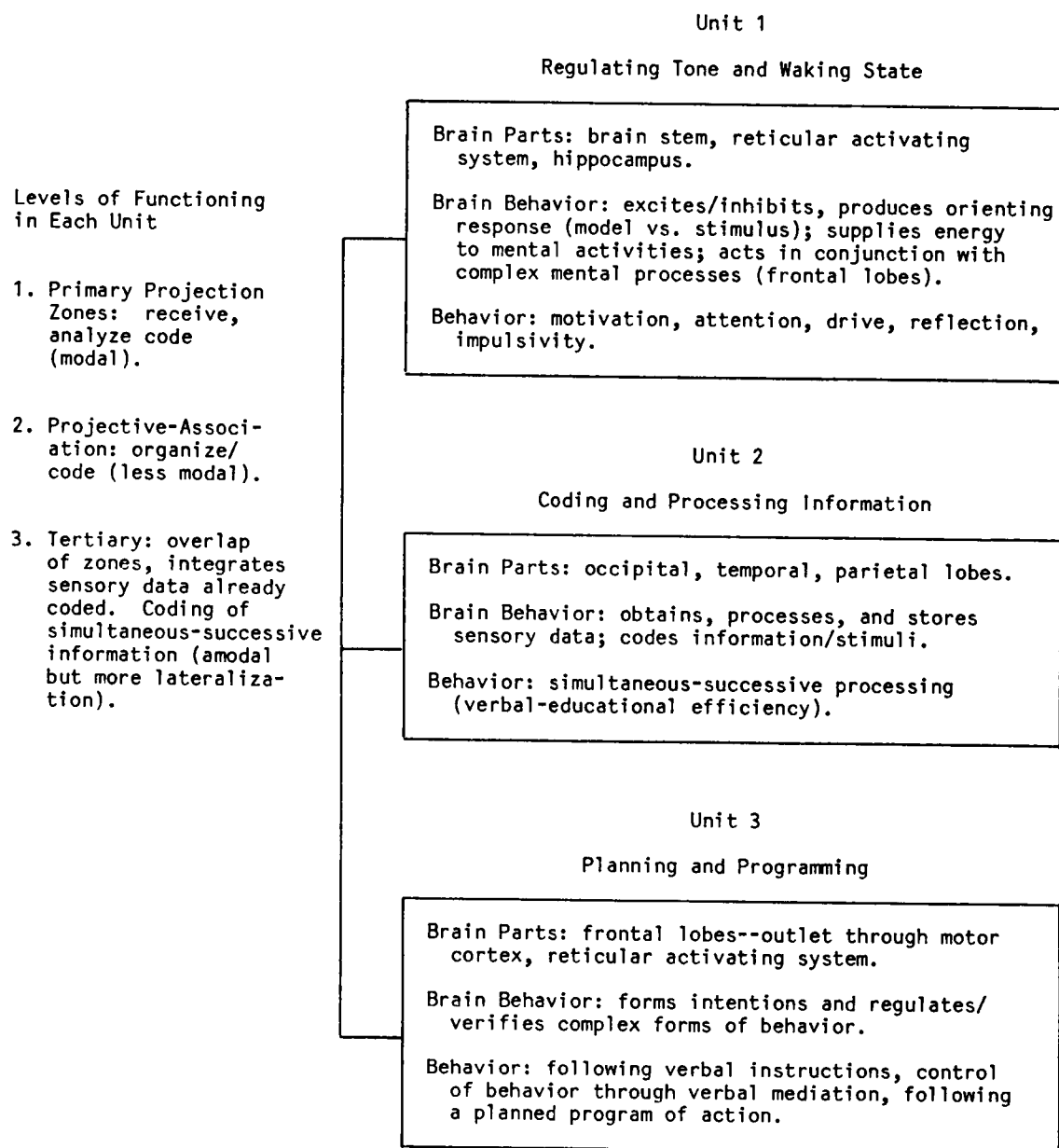


Figure 1. Schema of Luria's (1973) three functional units of the brain.

The first unit is really associated with motivation. The important role motivation plays in any performance including intellectual performance need not be mentioned here. What must be mentioned, however, is that motivation or, specifically, arousal level should be appropriate to the task at hand. The old Yerkes-Dodson law neatly describes for us the interaction between arousal level and the level of difficulty of a task. Concepts that are relevant to intellectual behavior are attention, drive, reflection-impulsivity, all of which are in some way primarily related to the first unit of the brain. The second unit is essentially concerned with coding. Coding behavior features prominently in all intelligence tests. The coding is of two kinds, simultaneous and successive. (p. 41)

They believe the third unit (planning and decision making function) is as much responsible for the verbal-educational efficiency as the coding unit. The third unit is important because it coordinates the various operations upon which intellectual responses are based.

Using Luria's simultaneous and successive process, Das et al. (1975) have proposed a model of information integration to expand on Luria's initial conceptualizations on the activity of the three cortical zones in each unit of the brain (see Figure 2). Luria's zones of activity--secondary and tertiary--are defined in terms of function, respectively, as (a) direct perception: selective attention to the stimulus field, (b) mnestic processes: the organization of stimulus (memory) traces from earlier experience, and (c) conceptual: synthesis of information for complex intellectual processes. As shown in the model proposed by Das et al. (1975), successive and simultaneous processing are of the three different varieties found in the different zones of cortical activity. Information, according to Luria, that is processed at the secondary or tertiary levels is amodal (i.e., processed without regard to sensory modalities).

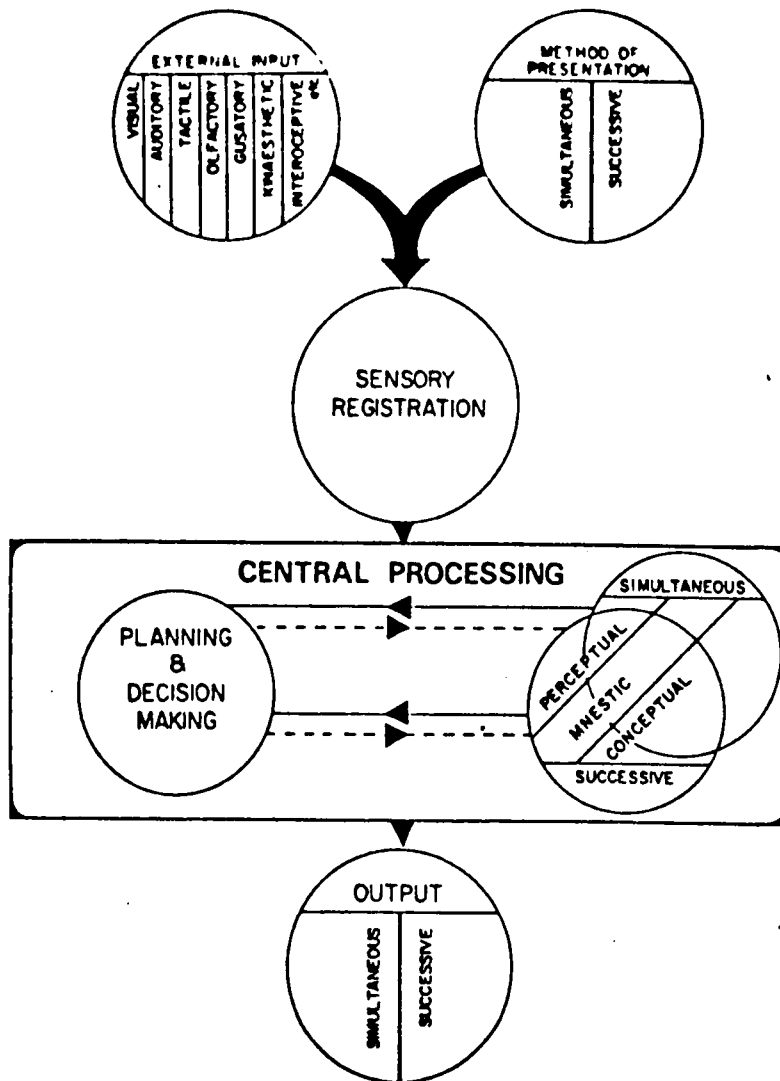


Figure 2. Diagram of the components of information processing. From "Simultaneous and successive synthesis: An alternate model for cognitive abilities" by J. P. Das, J. Kirby, and R. F. Jarman, 1975, *Psychological Bulletin*, 82, p. 90. Copyright 1975 by the American Psychological Association. Reprinted by permission.

A key component of the model proposed by Das et al. is the relationship between the sensory registration and the central processing unit. The control processing unit reads information registered by the sensory registration from external input (i.e., environmental stimuli). Once the information is transmitted into the central processing unit, it is organized into either successive or simultaneous groups at the three levels of cortical activity previously discussed. The decision-making and planning component uses the successive- and simultaneous-coded information to determine a plan of action.

In the context of this model of information processing, Das et al. (1975) provided definitions for simultaneous and successive processing:

Simultaneous integration refers to the synthesis of separate elements into groups, these groups often taking on spatial overtones. The essential nature of this sort of processing is that any portion of the result is at once surveyable without dependence upon its position in the whole. . . . Successive information processing refers to processing of information in a serial order. The important distinction between this type of information processing and simultaneous processing is that in successive processing the system is not totally surveyable at any point in time. Rather, a system of cues consecutively activates the components. (p. 89)

It should be noted that it is the central processing component that is of primary concern when assessing mental ability using a model of intelligence based on successive and simultaneous processing modes. The two modes of processing may be viewed as mediators between the stimulus inputs and response outputs. Which mode of processing is used by an individual to solve a problem or make decisions depends on

habits in thinking determined by social and genetic factors and by the mental processing demands of the task (Das et al., 1975, p. 91).

Verification of Successive and Simultaneous Factors

Evidence for a model of sequential and simultaneous processing was accumulated by Luria using a "syndrome analysis" procedure. Using this procedure, Luria studied the secondary symptoms of brain lesions and compared them to other normal and abnormal processes. The reliability of any hypothesis was based on the number of negatively or positively correlated symptoms (Luria & Arteméva, 1970). More recent investigations designed to provide evidence to support a model of successive and simultaneous processing have used factor analytic methods. Factor analysis has been used because of its ability to help define cognitive processes common to a set of tests using a range of individual differences.

Das (1972) studied the variability of simultaneous-successive processing across IQ groups. Using a battery of cognitive tests, Das tested 60 retarded and 60 nonretarded children. A factor analysis of the test scores in each group showed that for the nonretarded group a Simultaneous factor was defined by the Progressive Matrices, Cross-Modal Coding, Short-Term Visual Memory, and IQ tests. The successive factor for this group was defined by the Serial and Free Recall of Words and Memory for Designs scores. For the retarded group, the Successive and Simultaneous factors also emerged. The

Simultaneous factor was defined by the Progressive Matrices, Cross-Modal Coding, and the Memory for Designs tests. The successive and simultaneous variables were shown to be significantly involved in testing responses across IQ groups.

Molloy (1973) looked at the universality of successive and simultaneous processing in 6- and 10-year-old school children. Using a similar battery to Das, Molloy also included Speed as a third factor in accounting for the total variance in test scores. It was shown by factor loadings that Successive, Simultaneous, and Speed factors emerged across the two age groups with very similar correlation coefficients. In the 6-year-old group, the Successive factor accounted for 26% of the variance. It accounted for 29% of the variance in the 10-year-old group. Simultaneous processing accounted for 22% of the variance in the 6-year-old group and 26% in the 10-year-old group. Speed accounted for 22% and 13% of the variance in the 6- and 10-year-old groups, respectively.

Molloy also assessed the stability of the three factors by giving the battery of tests to 60 low socioeconomic status children and 60 middle to high socioeconomic status children. Both samples were approximately 10 years of age. The three factors again emerged in each group. With the high socioeconomic status group, Speed was a higher loading factor on Cross-Modal Coding than Simultaneous or Successive factors. In contrast, Speed was not a significant factor in the low socioeconomic group in the solution of Cross-Modal Coding problems.

Evidence for some difference in processing skill usage between high and low socioeconomic status groups was further supported by Das' (1973a) study. Das, using the same battery of tests as Molloy, tested white Canadian children and high-caste children in India. Again, the Successive, Simultaneous, and Speed factors were evident. It was found, however, in looking at factor loadings, that the Indians leaned toward a preference for successive mode processing for solving certain tasks. The same tasks often elicited simultaneous strategies from the white children. These results may point to a cultural preference in use of either strategy.

Cummins (1973) tried to elicit Successive and Simultaneous factors using a different battery of tests than that used by Das and Molloy. Cummins found in testing a sample of high school students that three factors emerged. Syllogisms, Similarities, Paired Associate Concrete Words, and Paper Folding tests all loaded on the Simultaneous factor. Digit Span, Paired Associate Abstract Words, and both Concrete and Abstract Memory Span tests loaded on the Successive factor. The third factor that emerged was a Divergent Thinking factor, which spanned both processing modes. Successive and Simultaneous factors each accounted for approximately 19% of the variance in test scores.

Canadian native children were studied by Krywaniuk (1974) for the three factors--Successive, Simultaneous, and Speed. Krywaniuk focused on the nature of the factors as well as their underlying processes. All the subjects were low-achieving students in the third

and fourth grades. The children were divided into two groups--a 15-hour-tutoring intervention group and a 3-hour-tutoring intervention group. The cognitive abilities of both groups were measured by a battery of tests before and after the intervention programs. A factor analysis of scores showed that three factors--Successive, Simultaneous, and Speed--did emerge. The marker tests for the Successive factor were Free Recall and Serial Recall. For simultaneous processing, Figure Copying, Memory for Designs, and Progressive Matrices were the highest factor loadings. Word Reading had the highest loading for the Speed factor. Successive and Simultaneous factors accounted for 28% and 23% of the variance, respectively.

Krywaniuk found, in comparing the results of pre- and posttest scores, that the 15-hour remediation program had an apparent effect on cognitive strategies. There was calculated a shift in factor loadings after intervention on such tests as the Progressive Matrices and Visual Short-Term Memory. This study provides some evidence that if the appropriate cognitive process is used for a given task, then optimal performance may result.

An investigation by Kirby (1976) involved 104 fourth-grade boys and 98 fourth-grade girls. Tests administered included the Colored Progressive Matrices, Figure Copying, Memory for Designs, Serial Recall, Visual Short-Term Memory, Digit Span Forward, Word Reading, and Color Naming. A varimax rotation performed on the factor matrix revealed a consistent loading of factors on the successive and simultaneous modes. This seems to override the alternative of dividing

the factors into Reasoning and Memory, which were involved in both processing modes.

Lawson (1976), with an expanded test battery, analyzed the scores of 70 fourth-grade children. The complex relationship between memory and simultaneous-successive processing was again focused on here. Substantial loadings on the Simultaneous and Successive factors of several short-term memory tests supported the argument that successive processing is not just associative learning or rote memory. The short-term memory tests used by Lawson appeared to require the use of different cognitive processing modes.

Patterns of cognitive abilities of children in Grades 1 and 4 were studied by Das and Molloy (1975). A battery of tests indicative of simultaneous and successive processing was administered to 60 boys in each grade. The test scores for each grade were subjected to principal component analysis. The analysis yielded three common factors: Simultaneous, Successive, and Speed. Although results were similar for the two grades, the Successive factor showed some variation. Namely, in Grade 4 children, the Successive factor was defined by the Visual Short-Term, Serial Recall and Free Recall tests. However, for Grade 1 children, Visual Short-Term Memory was more closely associated with Speed. In Grade 1, the Successive factor was defined by the Serial and Free Recall tests. The Simultaneous factor was more consistent in the comparison of the two grades, as was the Speed factor. Conclusions from this study were that Simultaneous and Successive variables in thinking were identifiable at Grade 1 and

Grade 4 levels with similar test findings. Also, some variations in the groups suggest developmental changes in information processing primarily because of Speed.

Ashman and Das (1980) attempted to delineate the planning and decision-making component included in the model of information processing by Das et al. (1975). The subjects for this investigation included 104 students in Grade 8. Five tests (Visual Search Task, Trail-Making Test, Verbal Fluency, Planned Composition, and Porteus Maze Test) were used to assess the Planning factor. Five tests (i.e., those used in Das' previous studies) were administered to assess simultaneous and successive processing. Varimax factors of Successive processing and Simultaneous processing again emerged. Ashman and Das found using principal component analysis that only three planning tests provided an orthogonal factor in comparison to the Successive and Simultaneous factors. Thus, the two coding factors may be prerequisites to good planning skills and therefore not entirely independent of each other. This appears to support a systems approach to brain functioning.

Successive and Simultaneous factors were isolated by Naglieri, Kaufman, Kaufman, and Kamphaus (1981) using a test battery of novel tasks. A sample of 77 normal children in grades K-6 were tested using tests for successive processing (WISC-R Digits Forward) and simultaneous processing (Progressive Matrices). Seven new tasks were constructed as part of the research on the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983a). Concept

Formation, Memory for Places, Overlapping Designs, and Triangles tests were used to assess simultaneous processing. Successive processing was tested by Sequential Hand Movements, Memory for Words, and Hand Patterning.

A two-factor varimax rotated solution reflected clear-cut Simultaneous and Successive factors. The six subtests believed to require simultaneous processing had loadings of .45 to .70 on the Simultaneous factor and failed to load above .32 on the Successive factor. The five tasks intended for measuring successive processing loaded .38 to .73 on the Successive factor but only loaded .25 and below on the Simultaneous factor. This study gave added support to the existence of successive- and simultaneous-processing abilities in school-age children and validated the model proposed by Das et al. (1975).

Kaufman, Kaufman, Kamphaus, and Naglieri (1982) performed another investigation to provide an independent cross-validation of the existence of successive and simultaneous processing in children and to study developmental changes across the preschool and elementary age range of the two processes. Subjects involved in the study were 580 children aged 3-0 to 12-6. The students were divided into four age groups and administered a tryout version (i.e., prestandardized form) of the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983a). Fourteen processing tests were administered to the subjects with different combinations of tests used in three forms of the battery. The Kiel-Wrigley criterion produced two factors for each analysis of

the four age groups. All but two of the tests for each factor loaded as predicted.

A developmental trend was noticed for both factors. At ages $5\frac{1}{2}$ to $6\frac{1}{2}$ and $7\frac{1}{2}$ to $8\frac{1}{2}$, simultaneous test scores loaded more heavily than sequential test scores. It was also noted that a General Intelligence (g) factor emerged for all four age groups. Across all ages, Triangles, Hand Movements, Memory for Words, and Concept Formation were the best measures of general ability with factor loadings in the .64 to .66 range.

This investigation provided data for a cross-validation of research by Das et al. (1979) on successive-simultaneous processing. The different weight of the factor loadings at the four age groupings supported the claim by Das et al. that it is not the nature of the stimulus (input) or response (output) that defines which factor is used but the type of mental processing required to solve the problem or make the decision.

The most significant results of the study by Kaufman et al. (1982) is the finding of developmental trends in use of successive or simultaneous processing. The developmental trends found were (a) there were lower Simultaneous loadings for several simultaneous tasks for older children than younger ones, (b) simultaneous tasks for older children loaded on the Sequential factor for ages 3 to $4\frac{1}{2}$, (c) two simultaneous tasks loaded more on the Sequential factor at ages $10\frac{1}{2}$ to $12\frac{1}{2}$ than at younger ages, and (d) there is a U-shaped relationship between age and the relative size of the Sequential and

Simultaneous factors. These results support the idea that children may change the modes of processing with the same tasks as they get older. Generally, there is a move from simultaneous processing (primarily based on perceptual skills) to sequential processing (primarily based on hypothetico-deductive approach) with mental maturity.

The K-ABC: Assessing Sequential and Simultaneous Processing

The Kaufman Assessment Battery for Children (K-ABC) (Kaufman & Kaufman, 1983a) is a measure of intelligence (mental processing) and achievement of 2½- to 12½-year-old children. The Mental Processing Scales of the K-ABC have tasks developed to measure sequential- and simultaneous-processing abilities as defined in the neuropsychological and cognitive theories reviewed in the previous section of this chapter. A new test, the K-ABC is already immersed in controversy and has been the subject of intense review, criticism and debate (e.g., Bracken, 1985; Kaufman, 1983, 1984; Keith, 1985; Mann, 1984). The primary point of controversy is the departure the Mental Processing Scales make from traditional intelligence tests in terms of content and the operational definition of intelligence. The Kaufmans (1983b) defined intelligence, as measured by the K-ABC, as an "individual's style of solving problems and processing information Regardless of more traditional approaches to the definition of intelligence, the K-ABC is predicated on the distinction between problem solving and the knowledge of facts" (p. 2).

The K-ABC was developed out of the authors' desire to develop a test battery that combined current research in clinical and neuropsychology with tasks that are similar to those found on conventional intelligence tests. A primary goal of Kaufman and Kaufman was to develop a measure of intelligence that had a strong theoretical and research base. It was also believed that the assessment of intelligence, based on an information-processing model, would have a more direct translation into educational activities in the classroom than traditional test batteries. Referring to some preliminary investigations in this area, the authors stated:

There is an intuitive relationship between processing style on the K-ABC and teaching or learning style in the classroom. In addition, several research investigations have supported the notion that effective learning takes place when the mode of teaching matches an individual's preferred processing style. (Kaufman & Kaufman, 1983b, p. 13)

Description of Mental Processing Scales

The intelligence scales on the K-ABC consist of three subtests for sequential processing and five subtests (for children ages 6 to 12½ years) for simultaneous processing. As described in the K-ABC Interpretative Manual (Kaufman & Kaufman, 1983b), each scale includes several subtests.

Sequential Processing Scale. This scale includes three subtests:

1. Hand Movements: This subtest measures the child's ability to copy the precise sequence of taps on the table with the fist, palm, or side of the hand performed by the examiner.

2. Number Recall: This subtest measures the child's ability to repeat in sequence a series of numbers spoken by examiner.

3. Word Order: This subtest measures the child's ability to point to silhouettes of common objects in the same order as these objects were named by examiner. It measures recall ability both with and without an interference task.

Simultaneous Processing Scale. This scale includes five subtests:

1. Gestalt Closure: This subtest measures the child's ability to "fill the gaps" mentally in a partially completed inkblot drawing and to name or describe that drawing.

2. Triangles: This subtest measures the child's ability to assemble several identical rubber triangles (blue on one side, yellow on the other) to match a picture of an abstract design.

3. Matrix Analogies: This subtest measures the child's ability to select the picture or design that best completes a 2-by-2 visual analogy.

4. Spatial Memory: This subtest measures the child's ability to recall the locations of pictures arranged randomly on a page.

5. Photo Series: This subtest measures the child's ability to organize a randomly placed array of photographs illustrating an event and then order them in their proper sequence.

Development of the K-ABC

The development of the K-ABC required several stages involving the piloting of experimental tasks and correlational analysis with other

known tests (e.g., Raven's Progressive Matrices) to come up with the best test items. Data from the pilot studies along with ratings of administration ease were used to develop four forms for a national tryout. Data obtained from the tryout on approximately 800 children were submitted to item analysis (difficulty and discrimination), internal consistency analysis (intercorrelation of test items), item bias analysis (sex and race), and factor analysis (construct validity). Subtests that met the statistical and clinical criteria were included in the national standardization. The standardization of the K-ABC was conducted with a sample of 2,000 children stratified by age, sex, geographic region, race/ethnic group, parental educational attainment, community size, and educational placement. Sample selection was based on the 1980 census figures.

Reliability of the K-ABC. The authors of the K-ABC reported split-half reliability coefficients for the global scales ranged from .89 to .97 for children 5 to 12½ years. They found that test-retest reliability coefficients for the global scales showed a very distinct developmental trend (i.e., reliability coefficients increased with age). The mean internal consistency reliability coefficients for the K-ABC ranged from .71 to .92 for school-age children (Kamphaus & Reynolds, 1984; Kaufman & Kaufman, 1983b).

Validity of the K-ABC. During the development of the K-ABC, a number of validity studies were performed to determine the construct, concurrent, and predictive validity of the instrument. Since the

publication of the test, numerous investigations have been conducted that have involved confirmatory analysis of the Sequential and Simultaneous factors on the test battery as well as regression analyses with various populations of children. In this section, a review of some of these studies will be provided to confirm the validity of the K-ABC as a measure of sequential- and simultaneous-processing abilities. These studies have provided more in-depth analyses of the properties of the mental processing scales and how they relate to various age, handicapped, and achievement groups.

One of the major areas of concern in research on the K-ABC is testing the construct validity of the mental processing (intelligence) scales. How well do the sequential and simultaneous measures fit the information processing modesl of Luria and Das? Factor analytic procedures were used in two studies (Kaufman & Kamphaus, 1984; Willson, Reynolds, Chatman, & Kaufman, 1985) to investigate the emergence of the processing modes on the two scales. Using the 2,000 subjects from the standardization sample, both investigations computed Sequential and Simultaneous factors as loading on their respective scales.

Kaufman and Kamphaus (1984) found significant sequential and simultaneous dimensions for 8 of 11 age groups in the standardization sample. Three of the age groups (2}, 3, and 5 years) yielded only one significant component. The two-factor-rotated solutions for each age group supported the fact that Sequential and Simultaneous factors accounted for the most variance in scores. Three-factor-varimax-

principal-factor solutions revealed that the data were best explained by three factors: Sequential, Simultaneous, and Achievement. All K-ABC subtests loaded higher on their designated factor than on the other factors in the solutions.

Willson et al. (1985) investigated the orthogonal factor structure of the K-ABC to provide evidence of the theoretical framework of the processing scales. Two- and three-factor solutions provided adequate loadings for each factor. Confirmatory analyses were performed to compare empirically derived test-factor structure with a theoretical structure, assuming complete factor independence. In the two-factor solutions, clear evidence was found for factorial independence. The three-factor solution showed that the Achievement Scale was not independent of the Mental Processing Scales. However, the size of the loadings did not support integration of Achievement with the Simultaneous or Successive Processing Scales.

Developmental Factors in K-ABC Test Results

With regard to the Achievement Scale loading on the two processing factors, Kaufman and Kamphaus (1984) also found that the Achievement subtests tended to have higher loadings on the Sequential factor at ages 4 through 6 years (designated as preoperational level) and again at ages 11 through 12½ years (designated as formal operational level). The same achievement subtests loaded higher on the Simultaneous factor for ages 7 through 10 years (designated as concrete operational level). These results support the developmental

trends in children's cognitive abilities consistent with results of the K-ABC national prestandardization testing and Piaget's theory of cognitive development. In both studies, factor analyses provided consistent loading of K-ABC achievement tests on the mental-processing factors. This confirmed that sequential and simultaneous processing are differentially related by age to school achievement.

Another study, using the K-ABC standardization sample, was conducted by Chatman, Reynolds, and Willson (1983). Discrepancy scores of the global scales on the K-ABC were examined (a) to determine the frequency of significant interscale and intrascale differences and (b) to determine the levels of interscale and subtest variability. It was found that 50% of the children in the standardization sample had sequential versus simultaneous absolute differences of at least 11 points and 25% had a sequential versus simultaneous discrepancy of 18 or more points. The average for the children was a simultaneous versus sequential difference of 12 points. This difference is close to the criterion for significance at the .05 level. The children's scores showed dispersion within scales and many exhibited significant strengths and weaknesses. The results of these analyses showed that differences in subtest and scale scores on the K-ABC are not uncommon. The pattern of test scores found on the standardization sample is not what is expected from normal children. However, it may be that the K-ABC results support the "normalcy" of

differences in the school-age population and address the need to consider student learning styles in curricula and instructional methods.

Reynolds, Willson, and Chatman (1984) continued to study developmental aspects of the K-ABC in a study in which they correlated raw scores of the K-ABC subtests to total raw scores on the sequential- and simultaneous-processing scales. Again, in this study, the 2,000 children of the K-ABC standardization sample were used along with the 615 children specifically selected for the sociocultural norms of the K-ABC. Results of the correlational analyses support a developmental aspect to raw score increases on the subtests of the K-ABC. The subtests of the two mental processing scales were correlated significantly with age (.60 to .70). The validity of age correlations also held up across race and sex with no significant differences ($p \leq .05$) among correlations for each race/gender group. It is suggested from these results that the K-ABC lacks significant race or gender bias that would support the need for differential test interpretation for any of the six age groups.

Test Bias of the K-ABC

The question of bias on the K-ABC was explored further by Reynolds, Willson, and Chatman (1985). The purpose of this study was to evaluate criterion-related validity of the K-ABC across race for blacks and whites. Subjects included 849 whites and 855 blacks drawn from the K-ABC norm sample and another SES-based sample. The children took a common set of tests and were grouped together in nine age groups. Predictive validities of Mental Processing and

Achievement scores were examined using separate regression equations for blacks and whites. Results of the regression analyses for age groups covering 2½ through 9 years showed a significant difference in prediction for whites and blacks in general achievement (K-ABC Achievement composite score). The correlations "favored" whites in terms of accuracy of prediction. The intercepts resulted in overprediction of achievement for blacks. Beginning at age 6½-7 years, separate mathematics and achievement scores were available. As with general achievement prediction, the math and reading predictions were more accurate with whites and over-predicted for blacks.

The Sequential and Mental Processing Composite score intercept differences for prediction of achievement seem to reflect differences in black and white educational experiences. A possible explanation is that sequential (linear, serial, analytical) processing is more consistent with school achievement tasks. The lack of effect of the simultaneous scale, in isolation, on achievement seems to support this conclusion. However, Kamphaus' study (1983) supported the fact that the Sequential and Simultaneous scales on the K-ABC are equally related to achievement. An alternative explanation may be that the educational process in the schools has failed to help blacks use their sequential processing skills to perform well on achievement tasks. This is supported by the fact that black children consistently scored higher on the K-ABC Sequential scale than the Simultaneous scale.

Naglieri (1986) addressed black-white performance differences on the K-ABC by comparing matched pairs of 172 black and white children. Test scores of the two groups were compared on the K-ABC and WISC-R. The mean scores on the WISC-R averaged 9 points higher for the white group, whereas on the K-ABC Mental Processing Composite the mean score difference was 6 points higher for the white students. None of these differences are statistically significant, suggesting comparable results for blacks and whites on the battery. However, blacks scored significantly lower than whites on the Simultaneous and Achievement scales of the K-ABC but not on the Sequential scale. The reduced differences or bias for blacks on the K-ABC, as compared to the WISC-R, as reported by Kaufman and Kaufman (1983b), was given limited support in this study. It does appear, however, that the major cause of reduced differences in black and white scores is because of the lower mean scores of whites on the K-ABC. Blacks' mean scores are about the same as they were with the WISC-R.

A concurrent validity study of the K-ABC was conducted by Zins and Barnett (1984) by comparing it to the Stanford-Binet and WISC-R. Forty subjects were selected ranging in ages from 6 to 12 years. None of the subjects were handicapped. A comparison of the scores obtained from the administration of the three intelligence measures showed the WISC-R Full Scale IQ and Stanford-Binet IQ mean scores to be higher than the K-ABC Mental Processing Composite (MPC) mean scores. Correlations between the WISC-R Verbal IQ and Sequential

scores and between the Simultaneous and MPC scores were all significant at the .001 level. The Performance IQ on the WISC-R was correlated with Sequential, Simultaneous, and Composite scores at a .001 level. The Full Scale IQ correlated with the MPC scores at the .001 level of significance. Significant correlations at the .001 level were calculated between the Stanford-Binet and the Sequential, Simultaneous, and MPC scores on the K-ABC.

Based on these results, it appears that the WISC-R and Stanford-Binet IQ scores are sufficiently related to the K-ABC scores to support the concurrent validity of the K-ABC for measuring intellectual functioning. Nevertheless, the IQ scores among the three tests may not be directly comparable. An examination of WISC-R subtests results indicated that there was a high correlation between them and the Sequential or Simultaneous Processing Scale subtest scores. Also, the Binet IQ scores correlated as much with the K-ABC Achievement Scale as with the Mental Processing Scale.

School Achievement and Simultaneous- Successive Processing

Various aptitude constructs have emerged from research designed to find predictors of important areas of achievement. There has been much effort placed on the validation of the aptitude constructs by establishing consistent correlations between predictors and criterion (field-achievement) measures. However, it is now considered as necessary, in order to validate an aptitude construct, to demonstrate how the construct explains an aptitude-treatment-criterion link in

question. Use of the term aptitude implies the intent of prediction for performance in the future. It also implies that if aptitude predicts performance (correlation), it also may be a (causal) factor in realizing a successful performance. Thus, it is inherent in aptitude theory that the aptitude-treatment interaction (ATI) link be made (Snow & Lohman, 1984, pp. 348-349).

One of the advantages of the simultaneous-successive model of intellectual functioning is its potential for being applied to ATI research. The fact that research supports the existence of these two coding processes benefits the investigation of them in relation to school achievement (Das et al., 1979, p. 71). Although researchers have not expected to find a simple relationship between achievement and simultaneous-successive coding skills, there is an expectancy to find a consistent link between particular areas of achievement and the use of these skills. Conceptually, the models of Luria (1973) and Das et al. (1975) indicate that areas of achievement requiring spatial integration (e.g., geometry) are expected to be related to the Simultaneous factor. Accordingly, areas of achievement requiring the serial ordering of otherwise unrelated information (e.g., phonics) are expected to be dependent more on successive processing. The complexities of language (reading, writing, speaking) require the capability to use both modes of information processing in order to be optimally effective.

Hartlage (1982) supported this perspective when he addressed differences in aptitude for areas of school achievement through

explanation of the asymmetrical function of the cerebral hemispheres. He believes a conceptual model of brain functioning compatible with current knowledge and clinical neurology supports some working assumptions on mental processing-school achievement relationships:

1. Reading skill, especially involving auditory sequencing, phonics, synthesis of meaning, and comprehension, is primarily dependent on posterior portions of the dominant (almost always left) cerebral hemisphere. Acquisition of some early reading skills, especially involving whole-word (traditional orthographic) and visual word matching (flash card) types of instruction may involve posterior portions of the right hemisphere.
2. Computation may involve either right or left cerebral hemisphere, depending on the complexity of the material and specific neuropsychological abilities required. For example, calculations involved in language contexts, such as WISC Arithmetic or "modern math" questions involving sequential logic require more left hemisphere function, while visualization of two dimensional problems (e.g., 237×49) involve somewhat greater reliance on the right hemisphere.
3. Spelling, being primarily an aspect of language, has strong dependence on the left hemisphere, although in very young children the acquisition of simple printing skills requires considerable right hemisphere involvement. . . . The way in which spelling is taught has some importance on which hemisphere is involved, however, since spelling from "rules," such as those governing positional statements of the letters i and c, makes much more demand on the left hemisphere than does mere copying from a visual example. (pp. 298-299)

Whether or not one assumes that successive or simultaneous processes occur in the left or right hemisphere as proposed by some (e.g., Bogen, 1969; Gazzaniga, 1975; Nebes, 1974) or, as Luria (1966a) found, that they were localized functions in the fronto-temporal region or occipital-parietal region, will not affect the interpretation of their effect on achievement tasks. There has been

sufficient validation of the two coding processes in mental functioning and enough convergence of cognitive theories to consider them primary factors in the learning process.

Achievement Groups and Processing Skills

Krywaniuk (1974), in his study of differences in processing skills between high- and low-achievers, also assessed the differences between groups on achievement measures. He used the Gates-MacGinitie Reading Test (vocabulary and comprehension), the Stanford Achievement Tests (word meaning, paragraph meaning, and work-study skills), local standardized spelling and reading tests, and the Schnell Reading Vocabulary Test. Factor analyses showed that simultaneous processing in the low-achieving group was moderately related to arithmetic and the Schnoell Reading Test. The relationship of simultaneous processing to arithmetic supports Sprecht's (1976) findings. A negative loading on the Schnoell test supports the idea that low-achieving children may use a more analytic (successive) approach on this task than a global (simultaneous) one.

In both high- and low-achieving groups, the Successive factor emerged. The high-achieving group had successive processing defined by Serial and Free Recall tests. Successive processing was also defined by the Serial Recall and Free Recall tests. Krywaniuk did find, when comparing high- and low-achievement groups across five factors, that Verbal-Educational, Simultaneous, and Successive factors are clearly identifiable. However, some achievement tests clustered

on the Successive factor for the high-achievers, whereas in the low-achievement group, the same tests loaded more on the Simultaneous factor. Based on these results, it appears that the success of the high-achievement group may have been significantly related to their use of more appropriate processing modes for the demands of the tasks.

Educable mentally retarded (EMR) children were studied by Cummins and Das (1980), who investigated the extent to which simultaneous and successive processing were related both to IQ performance and academic achievement. The WISC-R, Wide Range Achievement Test (WRAT), and Schonell Silent Reading Test were administered to 95 EMR children ranging in age from 12 to 15 years. Also, from Das' battery, the Raven's Progressive Matrices and Figure Copying were administered as tests for simultaneous processing, and Digit Span and Serial Recall were administered as tests for successive processing.

A principal-components factor analysis with a varimax rotation of WISC-R, simultaneous-successive, and achievement scores supported the relationship of the two processing skills to factors on the WISC-R and achievement measures. As predicted, the Perceptual Organization factor on the WISC-R was significantly related to Simultaneous Processing and WRAT Arithmetic. Successive Processing was related to WRAT Reading and Spelling. The fact that the Verbal Comprehension factor on the WISC-R was not related to any achievement measure suggested that EMR children do not apply verbal

abilities much to academic tasks. In the EMR group only the Freedom from Distractability factor and Successive Processing factor showed significant relationships to reading and spelling measures. This would suggest an ineffectiveness of EMR students in applying different processing strategies to academic tasks and to verbal skills in literacy-related activities.

A ninth-grade population was investigated by Shade (1983) to determine if there was a relationship between student's information-processing approaches and school achievement. A random sample of 135 students was selected. Students were divided into three groups of high-, average-, and low-achievers based on group achievement test batteries. All students in the sample were administered a battery of tests selected to measure different patterns of cognition, including analytical versus global thinking, part versus whole perception, and successive versus simultaneous processing.

An analysis of variance was performed using the three achievement groups for each test. On five of the six measures of cognitive processing, there was found a significant difference ($p < .01$) between each group on test scores. The differences were particularly notable when comparing the high- and low-achievement groups. Further study of the relationship of achievement differences to cognitive strategy was conducted by regression analyses. It was determined that the Group Embedded Figures Task (global versus analytical) and The Myers-Briggs Type Indicator (information-processing style) encompassed the same factors represented in the

other tests. Consequently, a discriminant analysis was performed using only these two tests.

The results of this analysis provided data that supported the suggestion that there are differences between high and low achievers in cognitive processing. Students who demonstrated a high level of school performance were found to be more analytical, linear thinkers (field-dependent), whereas low-achievers were more likely to be perceptual/sensory processors of information (field-dependent). These differences appear to be related to processes that predominately involve simultaneous and successive coding, whereas perceptual processing (Gestalt) is primarily defined by the Simultaneous factor.

The relationship of successive and simultaneous processing to classroom achievement was also investigated by Merritt and McCallum (1984). A sample of 157 college students was administered six cognitive tests from Das' battery. The scores from these tests were factor analyzed, and Successive and Simultaneous factors were identified. These factors were compared to the students' American College Test (ACT) scores and grade-point average (GPA). An analysis of these results suggests that simultaneous and successive processing substantially mediate classroom performance (GPA). However, the two processing modes were found to be nonhierarchical (i.e., students with high- or low-GPAs did not use one processing mode more than the other). Students who scored high in both sequential and simultaneous processing performed better (GPA) than those students who were high in only one mode. Students who were

high only in one processing mode performed better than those who were low in both. Those students in the diagonal groups (high-low, low-high) performed equally well in school. The Simultaneous factor was shown to have relative importance with its strong relationship to ACT scores. It is suggested that the complex reading (comprehension) required on the ACT may invoke more use of the simultaneous processing mode to meet task demand.

Achievement Test Scores and Processing Skills

Several studies have been conducted to establish a relationship between measure of simultaneous-successive processing and achievement test scores. Sprecht (1976), using Das' test battery and achievement measures in reading, math, vocabulary, and comprehension, attempted to relate cognitive variables to school achievement. Sixty-five high school students were involved in the study. Using math and reading achievement as criteria, two step-wise regression analyses were performed. It was found that mathematics achievement was best predicted by Figure Copying followed by Color Naming and Serial Recall. Reading scores were predicted best by Serial Recall and Word Reading. Based on these results, it was concluded that simultaneous processing, as represented by Figure Copying, is the optimal process for mathematics and that more reliance is placed on successive processing in reading tasks.

The development of the Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983a) provided the impetus for a number of

studies relating sequential and simultaneous processing scores to measures of achievement. Bolen, Childers, Durham, and Rouse (1983) examined the construct and concurrent validity of the K-ABC scales with the Wide Range Achievement Test (WRAT). A sample of 45 children in grades 3 through 6 was administered the K-ABC and WRAT. Results showed WRAT-Sequential scale correlations on Reading and Spelling were higher than WRAT-Simultaneous scale correlations on the same tests. The Simultaneous scale scores were related more to Arithmetic on the WRAT than did the Sequential scale scores.

A factor analysis of the K-ABC and WRAT scores resulted in a three-factor solution: Achievement, Sequential, and Simultaneous. Both WRAT and K-ABC achievement subtests were correlated more with the achievement factor than the processing factors. The Sequential factor was calculated to include all processing subtests except Gestalt Closure and WRAT Arithmetic. The Simultaneous factor appeared to be a weaker component than the other two factors, considering it accounted for only 9% of the variance in tests scores.

Concurrent validity of the K-ABC and WRAT was also investigated by Zins and Barnett (1984). The subjects in this study were 40 children ranging in age from 6-0 to 12-5. All students were administered the K-ABC and WRAT as part of a larger study involving use of the Binet and WISC-R scales. Reported Pearson product-moment correlation coefficients among WRAT subtests and K-ABC processing scales were (a) Sequential with Reading (.50), Spelling (.22), and Arithmetic (.35) and (b) Simultaneous with Reading (.55),

Spelling (.44), and Arithmetic (.46). Spelling was not related to sequential processing as had been expected. For elementary school children the spelling words on the WRAT may have required use of simultaneous rather than sequential processing. The words may have been easy enough for this group to enable them to by-pass the sequential mode and use primarily automatic and spatial responses.

Zins and Burnett (1984) also reported intercorrelations for the K-ABC Processing and the Achievement Scale subtests. No statistically significant differences in the correlations were found with Arithmetic on Simultaneous versus Sequential Processing or with Reading Understanding on Simultaneous versus Sequential Processing. A comparison of Reading Decoding on Simultaneous versus Sequential Processing did not achieve statistical significance either. These findings support the need for both coding processes to be integrated by the student if optimal success is to be achieved on academic tasks.

An investigation of concurrent and predictive validity of the K-ABC processing scales was conducted by Naglieri and Haddad (1984) with the WISC-R, PIAT, and WRAT test scores. The sample for this study was a group of 33 children in grades K through 6 who had been certified as learning disabled according to Nevada state guidelines. The K-ABC (Set 1) was administered in counterbalanced order with the WISC-R, PIAT, and WRAT (Set 2). As expected, results from the study showed that WRAT and PIAT mean standard scores were below the WISC-R mean standard scores. The same was true in comparing the K-ABC achievement mean standard scores with the Mental

Processing Composite mean standard scores. No significant differences were found in how the Simultaneous and Sequential scores correlated with the Verbal, Performance, and Full Scale WISC-R scores.

Most correlations between the K-ABC Sequential and Simultaneous Processing Scales and the PIAT and WRAT mean subtest scores were significant. The Simultaneous Scale was correlated significantly ($p < .001$) with the PIAT in Mathematics, Spelling, and Total Test scores. With the WRAT, it correlated significantly ($p < .001$) with Reading, Spelling, and Arithmetic scores. The Sequential Processing Scale scores were not significantly correlated with any of the PIAT scores (.30 being the highest) but were with all three WRAT subtest scores. The Simultaneous and Sequential Scale scores were not found to differ significantly in predictive ability in Reading Recognition, Reading Comprehension, and General Information on the PIAT. The Simultaneous Scale was significantly stronger than the Sequential Scale in predicting Mathematics scores and Spelling scores than was the Sequential Scale. On the WRAT no difference was found between the two processing scales in prediction.

Although a sequential/simultaneous discrepancy pattern was expected for a population of learning disabled children, it was not indicated by the results of this study. This may have been because of the heterogeneity of the group or the small sample size. Nevertheless, results of the study help confirm the idea that the relationship between simultaneous and successive processing and

achievement is a complex interaction of individual learning characteristics with the demands of a given task.

Childers, Durham, and Bolen (1985) compared scores on the Sequential and Simultaneous Scales of the K-ABC with scores on the California Achievement Test (CAT). Forty-four children in grades 4, 5, and 6 were administered the K-ABC in the fall. The CAT was given 6 months later. Pearson product-moment correlation coefficients were computed for each of the variable pairs on the K-ABC and the CAT. A summary of these results shows the K-ABC global scale measures (i.e., sequential, simultaneous, and achievement) were related significantly to composite scores for all CAT subtests. The K-ABC Achievement scale had a 40%-70% shared variance with the CAT composite score. The Sequential Scale scores on the K-ABC significantly correlated ($p < .001$) with the CAT composite Reading, Language, and Math scores. The K-ABC Simultaneous scale scores were correlated significantly (.001 level) with the CAT composite scores for Reading, Language, and Math.

These positive correlations between the K-ABC mental processing measures and CAT scores support the idea that academic performance is linked to mental processing skills. The fact that the K-ABC Achievement scale was clearly a better predictor of the CAT scores than the mental processing scales lends support to the assertion that achievement and intellectual ability are not the same concept.

Nesterak and Ferrari (1986) looked at the possibility of using intelligence test scores to improve prediction in achievement. The

authors used the WISC-R to determine Successive and Simultaneous factors. Achievement was measured by administration of the CAT. The sample included 63 children in grades 1 through 4. The full sample was divided into two subgroups: high achievers (above the 65th percentile on CAT) and low achievers (below the 25th percentile on CAT). Regression analyses of test scores showed that the Full Scale IQ was the single strongest predictor for all achievement scores. However, the successive- and simultaneous-processing scores also added to prediction. With regard to mathematical performance, the sequential processing scores along with the Full Scale IQ added significantly to the prediction of achievement. This was the only area of achievement where either sequential or simultaneous processing scores independently contributed significantly to performance prediction. Sequential and simultaneous processing were not found to be significantly correlated with placement in either a high- or low-achievement group.

Several conclusions can be drawn from the results of all these studies comparing successive- and simultaneous-processing skills to achievement or school performance. These results provide evidence that sequential and simultaneous processing are significantly interacting factors in achievement. It is also evident that the simultaneous-successive dichotomy fails to emerge as clear and distinctive among all samples. The tests used to measure them cannot be considered pure factor tests. In studies with broader age ranges of subjects, there were smaller processing-style differences than in

studies with narrower age ranges of subjects. It is entirely possible that a developmental factor is involved, producing a change in which processing skill is used regardless of the task. There is little support shown for the content area in the achievement measure dictating the type of processing skill used in problem solving. This, of course, is consistent with the assertions of Luria and Das. The use of either processing skill appears to depend significantly on developmental, habitual, and group-achievement factors that are not yet clearly defined.

Models of Reading Skill Development

In schools, especially at the primary level, the acquisition of reading skills is of primary concern to parents and educators when focusing on learning and performance in the classroom. The fact that reading is a fundamental learning skill and prerequisite to successful school performance has made it the subject of numerous research investigations. It has been demonstrated that there are both instructional and noninstructional variables that impose on a child's reading performance (Fry & Lagomarsino, 1982). With regard to understanding the early stages of reading skill development, it is the cognitive processing of information that has gained the attention of researchers as possibly the most important concept to consider. The cognitive processes involved in reading skill development have been primarily explained by reading specialists via the use of reading models. These models provide a means by which the functional role of

simultaneous and successive (sequential) processing in reading can be examined.

Henk, Readence, and Mason (1983) summarized three basic types of models that have been designed to address the developmental aspects of reading skill acquisition: (a) The "bottom-up" model is text-based, describing reading as moving from letters to words, phrases, paragraphs, and so forth; (b) the "top-down" model emphasizes meaning--reading is achieving congruence between what the text offers and what is already known; (c) the "interactive" model shows that reading is both a "bottom-up" and "top-down" process. Readers rely on their knowledge of syntax and semantics to process most reading material but also use graphophonic cues as necessary to decode more unfamiliar material.

Laberge and Samuels (1974) described a model of reading that is basically "bottom-up" in theory. However, unlike many "bottom-up" models, Laberge and Samuels' model includes perceptual units of various sizes that are used in word recognition and various routes information takes from word recognition to meaning. The model also includes an attentional aspect that may be the most important factor when considering which process (i.e., simultaneous or successive) is used in reading. Laberge and Samuels believed that regardless of whether a word is presented in isolation or context, beginning readers do letter-by-letter component processing. With skilled readers, regardless of how the word is presented, whole-word processing is performed. However, with the skilled reader, if the word is

unfamiliar, he/she will drop down to a smaller unit to recognize the word (i.e., use more component processing). Skilled readers use different size units depending on familiarity with the word(s) and the purpose for reading. Thus, the developmental sequence is from smaller to larger unit processing.

In addition to the unit-processing concept, LaBerge and Samuels incorporated in their model the variable of attention. Attention is an important variable because it is required in differing amounts for smaller versus larger units of reading material. Considering that there is only a limited amount of attention for a given time period, it is important to have enough attention for both decoding and comprehension. In this context, LaBerge and Samuels saw the beginning reader as having a problem. Decoding requires so much attention that there is not enough left for comprehension. To comprehend, a beginning reader must alternatively switch back and forth from decoding to comprehension. This is a relatively slow process that often interferes with remembering what is read. However, for the skilled reader, attention is employed differently. The skilled reader can decode and comprehend simultaneously. When decoding requires little attention and attention is used primarily for comprehension, the reader is considered an automatic decoder. Thus, automatic decoders can be considered whole-word (or larger unit) simultaneous readers. Nonautomatic decoders are considered component-letter processors (or smaller-unit) successive readers.

The importance of automatic processing in reading performance was also recognized by Schneider and Shiffrin (1977). They proposed two different attention mechanisms that appear to be particularly useful for models of reading involving language processing. The first attention mechanism is called "controlled processing," which refers to selective attention. Controlled processes are attention-demanding and are carried out sequentially. These processes are learned and can be modified by instruction to become more efficient. The second attention mechanism is termed "automatic processing." Automatic processes are not attention demanding and occur in parallel with other processes (e.g., controlling) without disrupting them. These processes are not easily learned and are not easily modified by instruction.

The idea of considering reading processes in terms of attention demands and the different types of information processing was also addressed by Perfetti and Lesgold (1981) in an interactive model. Their Verbal Coding Efficiency Model of reading proposes that short-term memory (sequencing) carries out both word decoding and comprehension functions. However, as LaBerge and Samuels (1974) suggested, the skill of reading comprehension is hindered by the requirements of handling the decoding process (controlled processing). In the Verbal Coding Efficiency Model, the efficient activation of higher order lexical and semantic units requires the development of automatic-word processing. This is based on Rumelhart's (1977) theory of an interactive process in reading. This process is based on the assumption that information comes into the cognitive system in

coded format and is held in memory for only a short time. While held in memory, the codes activate automatically a corresponding memory location, referred to as a node. Activation occurs not only to a specific node, but to neighboring nodes within the same level. Rumelhart describes this process as "spreading activation." In the interactive reading model, this activation, depending on the initial encoding response, can occur between levels of processing. These levels correspond to types of sources of information, including phonological, visual-orthographic, syntactic, and semantic levels.

An interactive model of reading stresses simultaneous-processing skills as necessary for good reading performance. Thus, word coding strategies are effective if they lead to quick access of lexical and semantic memory locations. Beginning readers during initial skill acquisition and poor readers appear to rely on serial- or successive-processing strategies involving letters and smaller grapheme-phoneme correspondence. Serial processes are considered to be time consuming and attention demanding, resulting in limited higher-level (simultaneous) processing efficiency. Mature readers, on the other hand, tend to use simultaneous processing with multiletter units, whole words, and independent-sentence segments. Simultaneous processing is then considered fast-acting and automatic and can be directed as such to comprehension functions involving the integration of various levels of information.

Taylor and Taylor (1983) have proposed an interactive model of reading that includes an elaboration of the concepts presented by

LaBerge and Samuels (1974) and Perfetti and Roth (1981). In the Bilateral Cooperative (BLC) model, it is shown that the reading process involves two parallel tracks of interacting processes. The LEFT track involves functional relationships and sequentially ordered material, including phonetic-coding and syntax. In relation to reading comprehension, it functions in the areas of analytical and logical thinking. The RIGHT track is involved primarily in patterns and previously seen patterns. It relates the words and phrases being read to the "real world." The functions of the RIGHT track are global, parallel, and simultaneous. Both tracks cooperate in extracting the meaning from the printed page, interacting at selected connecting points. The tracks operate independently of each other between connecting points.

In the BLC model, Taylor and Taylor (1983) presented the learning process in reading in three phases:

Learn a handful of words by their whole visual shapes (RIGHT whole word recognition based on visual features);
 learn to analyze words into their parts (LEFT analysis);
 learn once more to recognize the wholes, based on the securer knowledge of parts (RIGHT whole word based on letter identities). (p. 385)

This three-phased learning applies not only to words but also to letters, phrases, paragraphs, and whole texts. For example, at the letter level, a child first learns the gross shape of letters, then notes the same and different features in letters, and in the third phase recognizes the whole letters again based on a knowledge of their features. At the word level, the child learns a handful of sight words to have enough words with letters in common for analysis. The

analysis procedure is processed and words compared while new sight words are introduced. New letter-sound relationships are learned. In this way, the child develops both analytic and wholistic routes to word recognition. As mature readers, children read a familiar word as a whole visual pattern (simultaneous) and an unfamiliar word by phonetic analysis (sequential).

Unlike Laberge and Samuels (1974), Taylor and Taylor believed it best to train children in a cooperative approach to reading using both the LEFT and RIGHT tracks simultaneously. Laberge and Samuels believed in training each reading subskill to a point where it becomes automatic before learning the next subskill. In contrast, Taylor and Taylor suggested learning a few related reading subskills together and emphasizing one or the other as the reading material demands. This, they asserted, allows for an easier and more efficient integration of skills as reading ability develops.

The reading models presented above delineate the roles of sequential and simultaneous processing in the acquisition of reading skills. The concepts of information processing these models include parallel the model of information processing proposed by Das et al. (1975). Research on achievement, related to the model of Das et al. (1975), has provided two complementary perspectives on the roles of sequential and simultaneous processing in reading. The first perspective, developed from factor analysis results, supports the idea that there is a separate verbal-educational factor (Das, 1973b; Krywaniuk, 1974; Sprecht, 1976). The reading achievement factor is

partially separable from the information processing battery. The second perspective, based on regression analyses (Krywaniuk, 1974; Sprecht, 1976) and factor scores (Cummins & Das, 1980, Kirby & Das, 1977), leads to the view that reading achievement is dependent on both simultaneous and successive processes. This preliminary research supports the idea that sequential coding is most important in the beginning stages of reading. Reading achievement, after initial skill acquisition, seems to be equally dependent on both coding processes. However, with the proficient readers more reliance is put on simultaneous processing. Researchers with this perspective align simultaneous processing with automatic-word decoding and comprehension and align phonic analysis, lexical access, and semantic access with sequential processing.

Empirical support for the reading models presented above and for the conclusions on the role of sequential and simultaneous processing in reading is limited at this time. Reviewed below are some recent studies that have been focused on individual and group differences in reading skill acquisition and how these differences may be related to information-processing skills.

Phonological Skills and Early Reading

The importance of phonological coding in early reading skill acquisition was investigated by Lean and Arbuckle (1984) and Tunmer and Nesdale (1985). Both studies provided support for stating that phonological coding was an important factor in reading skill

development. Prereaders were tested by Lean and Arbuckle using two age groups (3½ through 5 years and 5 through 5½ years). A large phonetic-similarity effect on prereading skills was found in both age groups. Cross-sectional and longitudinal comparisons of the two age groups did not show any evidence of developmental change in the magnitude of phonetic-similarity effect on performance on rhyming and nonrhyming letter sets.

Tunmer and Nesdale studied first-grade children by administering tests of verbal intelligence, phonemic segmentation, and reading achievement. They found that nondiagraph word segmentation had a stronger relationship to reading achievement than diagraph word segmentation. An analysis of the data (path analysis) indicated that phonological awareness scores were related to reading comprehension indirectly through recoding and that students strong in phonic analysis were more likely to have better reading comprehension skill scores than those students with below-average phonic analysis skills.

Four recent studies have been conducted to investigate variables that are believed to contribute individually and cumulatively to the development of reading skills. Share, Jorm, MacLean, and Matthews (1984) conducted an investigation to determine the sources of individual differences in reading achievement. Individual attributes in prereading abilities, oral language, motor skills, personality, and home background were assessed on 548 kindergarten and first-grade children upon school entry. Reading achievement was assessed at the

end of the school year. Regression analyses showed that the strongest single predictor for individual reading was phonological processing (i.e., correct sequencing of letter-sound associations in decoding). It was correlated .65 with kindergarten and .62 with first-grade students' reading scores. The regression analyses of reading achievement on ability-composition measures revealed that 73% of the variance in Grade 1 reading achievement can be accounted for by attributes measured at the kindergarten level. Thus, it may be concluded that although phonological-processing ability is a prime predictor of early reading acquisition in first grade, it is the presence of this ability prior to Grade 1 that is the stronger determinant of reading performance. This may be because better developed automatic processing in first-grade students facilitates better reading performance during first grade.

Stanovich, Cunningham, and Feeman (1984a) studied the role of early sequential (component) processing in the development of good reading skills. Fifty-six first-grade children were assessed on measures of general intelligence, decoding speed, phonological awareness, and listening comprehension. Hierarchical multiple regression analyses resulted in phonological awareness measures accounting for the most variance in reading achievement (24.4%). Decoding-speed variables explained a significant amount of variance also with 14.2%. In addition, the results showed that even when general intelligence and language comprehension factors were entered into the equation, phonological awareness and decoding-speed variables

still made significant contributions to predictive accuracy in reading comprehension.

Although there is little doubt that intelligence and language factors are moderately good predictors of reading ability, the developmental aspects of reading-skill acquisition appear to be supported by the hierarchical placing of phonological processing and decoding speed in predicting reading comprehension. These findings are supportive of theories that include the idea that the ability to decode a word rapidly into a phonological code (automatic processing) is an important determinant of reading comprehension proficiency (e.g., Perfetti & Roth, 1981).

Processing Skills, Reading and Language Awareness

Leong (1984) studied the role of cognitive processing and language awareness in relation to reading. A sample for the study consisted of 56 second-graders and 64 fourth-graders from a western Canadian city. Cognitive processing was measured using successive- and simultaneous-processing measures reported by Das et al. (1975, 1979). For language awareness, three tasks were used to test phonological awareness; lexical, surface-, and deep-structure ambiguities; and appreciation of sentence incongruities. Reading was assessed by the Revised Schnoell Word Recognition Test.

A principal component factor analysis of the cognitive-processing scores showed these variables loaded on their respective simultaneous and successive modes. The children in each grade were divided into

four groups based on scores in the successive-simultaneous dimensions. A 2 (Grade) x 4 (Cognitive Processing) ANOVA was performed for each of the language awareness tasks to examine the difference in simultaneous- and successive-processing scores. For phonological awareness, appreciation of ambiguities, comprehension of incongruities, and reading, the main statistical effects for grade and cognitive processing were significant at the .01 level. The results provide some evidence that children, grouped by Simultaneous-Successive factor scores, differ in their ability on language awareness and reading tasks.

Further analysis by Leong of the contribution of language awareness and simultaneous-successive syntheses to reading was completed with stepwise multiple regression analyses. He found that the direct effect of simultaneous processing on reading was .05, whereas the total of indirect effect was .22. By comparison, the language awareness tasks had a greater direct effect on reading as shown by a path coefficient of .68. These results provide some evidence to support the idea that although simultaneous and successive processing are important to reading performance, their role appears to be one of providing underpinning to reading development. Thus, the effect of simultaneous-successive processing is mediated by language awareness, which has a more direct effect on acquiring reading skills.

An investigation of the relationship between classroom learning activities, cognitive abilities, and reading (Evans & Carr, 1985) provided results that differed from those of Leong's with regard to the

direct effect of language awareness on reading. Two sets of 10 classrooms involving 50 teachers in kindergarten through grade 3 were involved in the study. Each group was exposed to a different reading curriculum (i.e., language experience versus routine [phonics] approach). Measurements were taken in five areas of development: information processing, linguistic maturity, social skills, reading achievement, and mathematics achievement. No differences between curricula were found in the various measures of social skill and information processing (i.e., Verbal Fluency, Designs from Memory, Progressive Matrices, and Classification). With respect to language competence, there was no difference in the two curriculum groups. However, in reading and mathematics differences did emerge between groups. The routine (phonics) group was found to be superior to the language experience group on the cloze task, in answering questions about a primer passage, and on tests of number concepts and number skills. In addition, it was shown that with the phonics-oriented group, reading scores were correlated positively with the various cognitive measures. However, significant negative correlations between linguistic ability and reading skill were observed in the language-experience group.

These results support the argument that linguistic ability facilitates beginning reading only after specific component skills have been acquired. It may be that the phonics-oriented group did better in basic-level reading than the language experience group because of better training in text-driven, component processing. These skills

may have been developed to an automatic level, allowing the students to attend more to higher-level comprehension tasks.

Processing Skills and Reading Vocabulary

The development of word decoding skills in young readers has been recently investigated in four studies. Stanovich, Cunningham, and Feeman (1984b) studied 56 first-grade children divided into groups of skilled and unskilled readers. The children were tested in the fall and spring on lists of words and random and coherent paragraphs. It was suggested based on the results, that less-skilled readers of this age may perform poorly on coherent paragraphs if they have poor decoding skills, not because they have an inability to use context to facilitate word recognition.

Does visual or phonetic learning take place in the first stage of reading the printed word? Ehri and Wilce (1985) investigated this question with kindergarten children grouped according to their ability to read words: (a) prereaders (no words), (b) novices (a few words), and (c) veterans (several words). The students were taught two kinds of word spellings--phonetic and visual. It was found that the prereaders learned the visual spellings better than the phonetic spellings. However, the novices and veterans learned to read the phonetic spellings more easily. These results supported the belief that in the process of early-reading acquisition, young children shift from visual-cue (simultaneous) processing of words to phonetic-cue (sequential) processing. This transitional-learning process appears to

provide some explanation as to how children first become proficient in word recognition.

The growth of sight vocabulary in elementary students was also the subject of Adams and Huggins' (1985) study. Above and below average readers in the second through fifth grades were tested on their sight vocabularies. A series of four experiments was performed in which each experiment had the children read words orally in order or read words as a last-content word in a meaningful sentence. In Experiments 1 and 2, it was found that there were significant differences between each grade in number of words read correctly and between good and poor readers. In both context reading tests, the correlation between correctly read words and average stanine scores on standardized reading tests ranged from .67 to .94. In Experiments 3 and 4, the differences in word reading skills and reading achievement scores for a higher-socioeconomic (SES) group were qualitatively similar to the lower-SES students in Experiments 1 and 2. Correlations between performance on word-reading tasks in and out of context ranged from .82 to .95. There was no hint that the relationship between word reading and reading achievement changed for students between grade levels.

The word-recognition levels exhibited in the experiments demonstrated the importance of context in helping the reader with words that were only partially familiar. The data support the model of Perfetti and Roth (1981) showing that words attain sight word status in three stages. The first stage is the defining of word

characteristics through sight acquisition (simultaneous processing) without benefit of orthography (i.e., knowledge of spelling rules). The second stage of word recognition is transitional in that words are not sufficiently recognized to support automatic processing. Word recognition at this stage is helped most by the presence of meaningful context. The third stage of mastery permits the level of word recognition to be automatic. This, of course, is a characteristic of skilled readers.

Synthesis of the Literature

The development of models of information processing, emphasizing the use of sequential and simultaneous coding skills, is rooted in research on brain asymmetry and neuropsychology. According to Luria (1973) and Das et al. (1975), the higher cortical functioning of the brain is divided into three levels of activity. The types of activity at these three levels include perception, organization, and conceptualization, respectively. As elaborated by Das et al. (1975), sequential and simultaneous processing operate on the conceptual level without regard to the sensory modalities. Consequently, an individual selects either processing mode based primarily on the mental-processing demands of the task, not on the nature of the stimuli.

The support for the sequential and simultaneous model of information processing, gathered from factor analytic studies, fostered investigation into the underlying mental processes common to learning performance in the classroom. It has been proposed by researchers

that a sequential and simultaneous information processing model provides a sound basis for empirically relating aptitude for learning to specific-skill acquisition in school.

The assessment of sequential and simultaneous constructs has been conducted by researchers using several psychometric batteries developed in the past two decades. A recently developed test of intelligence, the Kautman Assessment Battery for Children (K-ABC) (1983a), has been shown to be a valid, standardized assessment tool for measuring the two cognitive processing skills. From factor analytic studies, researchers have found that Sequential and Simultaneous factors emerge at each age level tested. Standardization studies on the K-ABC produced data that supported the suggestion that a modest variability between the two factors was normal in children. No significant test bias by age, sex, or race was found with the K-ABC.

The research on cognitive information processing supports the fact that simultaneous and sequential coding are significant factors in the acquisition of reading skills. Research data provided supporting evidence that the use of these coding skills in problem-solving tasks and in the different levels of reading is dependent on several factors. These factors include age, previous learning experience, and task demands.

During the acquisition of reading skills, beginning readers move through various stages of learning that include the employment of different processing skills at each stage. It is supported by the research reviewed that beginning readers move from initial shape

recognition of letters (simultaneous processing), to decoding skills using phonological awareness (sequential processing), to whole word (automatic) decoding (simultaneous processing), to text integration (simultaneous processing) for reading comprehension. Beginning readers appear to rely primarily on component (essentially sequential) processing and become more efficient in reading when larger units of material can be processed automatically. After initial skill acquisition (i.e., beginning to decode words automatically), beginning readers are believed to use both simultaneous and sequential processing as needed to be proficient. Once skills are integrated, the high achievers in reading rely more on simultaneous processing.

The research on the less-skilled readers provided some evidence to support the fact that over-dependence on one coding process may inhibit reading skill development. These results also supported the fact that children who initially fail to develop good phonics decoding skills (sequential processing) lag behind in overall reading development.

CHAPTER III

METHODS AND PROCEDURES

Hypotheses

The investigations on sequential and simultaneous processing factors and their relationship to student learning or school achievement provide data that support the development of multiple hypotheses. Eleven hypotheses were proposed in the current investigation to address four areas of research on the relationship of sequential and simultaneous processing to reading ability among first-grade students.

There were three hypotheses tested that involved the study of the relationship of sequential- and simultaneous-processing abilities to reading skills:

1. Hypothesis 1: First-grade students' entry-level reading skills are related to their assessed sequential- and simultaneous-processing abilities.

2. Hypothesis 2: First-grade students' progress in reading skill development during the school year is related to assessed sequential- and simultaneous-processing abilities.

3. Hypothesis 3: First-grade students with lower classroom reading performance have lower assessed sequential- and simultaneous-processing abilities than students with higher classroom reading performance.

There were four hypotheses tested that involved the study of the role of sequential- and simultaneous-processing abilities as prerequisites to the development of reading skills:

1. Hypothesis 4: Students in the first grade with assessed sequential-processing ability higher than simultaneous-processing ability have higher scores on measures of phonics skills than those students with sequential ability equal to or lower than simultaneous ability.

2. Hypothesis 5: First-grade students with assessed simultaneous-processing ability higher than sequential-processing ability have higher scores on measures of reading comprehension than those students with simultaneous ability equal to or lower than sequential ability.

3. Hypothesis 6: Students in the first grade with deficient sequential-processing ability perform below students not deficient in sequential-processing ability in overall-reading achievement.

4. Hypothesis 7: Students in the first grade with deficient sequential-processing ability have less improvement in overall-reading skill during the school year than students who do not have deficient sequential-processing ability.

There were two hypotheses tested that involved the study of the effects of relying primarily on either sequential or simultaneous processing in reading:

1. Hypothesis 8: First-grade students who rely more on either sequential or simultaneous processing in learning have less

improvement in reading skills during the school year than those students with no difference between the use of the two processing abilities.

2. Hypothesis 9: First-grade students who rely more on either sequential or simultaneous processing in learning perform at a lower level in the classroom than those students with no difference between use of the two processing abilities.

There were two hypotheses tested that involved the study of the comparison of processing abilities and reading achievement scores in predicting end-of-the-year reading level:

1. Hypothesis 10: Measures of sequential- and simultaneous-processing ability predict better than grade-entry measures of reading ability the end-of-the-year reading level of first-grade students.

2. Hypothesis 11: Measures of sequential- and simultaneous-processing ability predict better than grade-entry total reading scores the performance levels achieved in the reading curriculum by first-grade students.

Research Design

In this investigation, an ex post facto research design was used. The subjects in the first grade were evaluated in the fall and spring on a group achievement test in reading, measured on classroom reading performance at the end of the school year, and assessed at the beginning of the school year as to their sequential- and

simultaneous-processing abilities. The data generated from these evaluation procedures were used to test the proposed hypotheses.

Ex post facto research as defined by Kerlinger (1973) "is systematic empirical inquiry in which the scientist does not have direct control of independent variables because their manifestations have already occurred or because they are inherently not manipulable" (p. 379). The purpose of ex post factor research is the same as that of experimental research: establish the empirical validity of the stated hypotheses (if x, then y). The basic difference is the control factor with the independent variables. However, this difference has a crucial impact on the confidence with which one can make conclusions about the relationship between x and y.

In this investigation, multiple hypotheses were tested. Test scores on the independent variables, sequential and simultaneous processing, were related to various dependent variable measures representing reading achievement in the first grade. Reading achievement variables included fall and spring achievement test scores in reading, skill-improvement scores in reading between fall and spring achievement testing, and performance levels in the classroom in the reading program. The testing of multiple hypotheses provided a broader perspective from which to analyze the relationship between the independent and dependent variables and to draw conclusions about the meaning of that relationship.

Subjects

The subjects in this investigation were 86 students enrolled in five first-grade classrooms in the Alcoa City School system in Alcoa, Tennessee. During the school year, 107 first-graders were enrolled in the Alcoa elementary school's five first-grade classrooms. The 86 students were selected as subjects according to three criteria: (a) It was the student's first enrollment in a first grade, (b) the student's chronological age did not exceed 84 months (i.e., 7 years) by the beginning of the school year (i.e., September 1), and (c) initially, the student was not certified as having a handicap as defined under Tennessee Department of Education Rules, Regulations, and Minimum Standards. In reference to the third criterion, three students included in the sample were certified and verified in April of the school year as having mild learning disabilities. Seven additional students in the sample were informally referred (i.e., verbal request) in May of the school year for possible learning disabilities.

The subjects included 44 boys and 42 girls ranging in age from 71 months to 82 months (mean = 75.3, standard deviation = 2.4) at the beginning of the school year. A mean age of 76.4 months was calculated for the students at the time of the pretesting of reading achievement. Posttesting of reading achievement in April of the school year showed a mean age of 83.1 months for the students.

With respect to demographic characteristics, the students included approximately 26% minorities (23.5% black, 2.4% Asian). Black males represented over 9% of the subjects and black females almost 14%. Of

the 74% Caucasians in the sample, 41% were males and 33% females. Socioeconomic levels were estimated from a review of permanent school records referring to occupations for parents and lunchroom-eligibility payments. This survey suggested that 13% of the students in the sample were from families with parents on welfare-dependent status or performing part-time service jobs. Eighteen percent of the students' families had incomes from skilled or semi-skilled blue-collar jobs. Forty-eight percent of the students' family wage earners had craftsmen, technician, and clerical jobs. Occupations for the remaining 21% of the students' families were included under administrative (supervisory) or professional categories (e.g., physician, teacher, lawyer).

Instrumentation

California Achievement Tests (CAT)

The California Achievement Tests (CAT) (1979a) were used to assess the reading achievement levels in September (Level 11, Form C) and in April (Level 12, Form C). The CAT's purpose is to provide an educational evaluation system that provides both norm-referenced and objectives-based information. Forms C and D of the CAT measure achievement in the areas of prereading, reading, spelling, language, mathematics, and reference skills. The CAT assesses reading skills in the first grade in the areas of phonic analysis, structural analysis, reading vocabulary, and reading comprehension.

The CAT was selected as the instrument for measuring reading achievement in this investigation because its reading tests were

designed to measure reading skills development through pre- and posttesting over a school year. In addition, the CAT was selected and has been used by the Alcoa City Schools to measure entry-level skills of first-grade students and end-of-the-year skill levels. Scores from the CAT are used by teachers as one of the primary criteria for determining (a) group placement in each classroom, (b) eligibility for Chapter I classes, (c) promotion/retention recommendations, and (d) progress in achievement over a school year. Also, the reading skills assessed on the CAT are consistent with the skill objectives offered through the Holt Basic Reading System (Everetts, Weiss, & Cruikshank, 1977), which is the curriculum program used in the first grade at Alcoa Elementary School.

Measures of test-retest reliability on the CAT (1979b, pp. 113-114) for Level 11 (6-month interval) were reported by the publisher as .70 for the Phonic Analysis test, .58 for the Reading Vocabulary test, .50 for the Reading Comprehension test, and .72 for the Total Reading battery. On level 12, the test-retest reliability coefficients for the following test were reported: Phonic Analysis, .80; Structural Analysis, .50; Reading Vocabulary, .78; and Reading Comprehension, .73. Fall-spring correlation coefficients for Level 11 and Level 12 were calculated at .60 for Phonic Analysis, .49 for Reading Vocabulary, and .41 for Reading Comprehension.

According to the publisher, the validity of the CAT is primarily based on its content. Development of the various tests on the CAT began with the development of objectives. Curriculum guides and

instructional materials were obtained from all state departments of education and most major cities. These materials were reviewed and the basic skills identified as common to most curricula compared with the objectives found in the Prescriptive Reading Inventory (PRI). The objectives obtained from this process were the basis for the objectives included in the CAT (1979b, p. 7). Item selection for the CAT was based on several criteria, including (a) discrimination in difficulty among grades and achievement groups, (b) consistency with the entire test, and (c) contribution to test reliability.

The standardization of the CAT was designed to provide national norms for both fall and spring testing. The first-grade population in the standardization included over 7,000 fall-to-spring matched cases with 3,668 students matched on 11C and 12C levels. In order to obtain a representative sample of students, the CAT standardization population was stratified by geographic region, size of enrollment, proportionate minority representation, and a demographic index based on community characteristics (CAT, 1979b, pp. 54-56).

The Kaufman Assessment Battery for Children (K-ABC)

The mental processing scales of the Kaufman Assessment Battery for Children (K-ABC) (Kaufman & Kaufman, 1983a) were used to assess the sequential- and simultaneous-processing skills of the first graders in this investigation. The K-ABC is an individually administered measure of intelligence for normal and exceptional children ages 2½ through 12½ years. Intelligence is defined as a style of

problem solving and processing information (Kaufman & Kaufman, 1983b). The Sequential- and Simultaneous-Processing Scales on the K-ABC represent a model of thinking based on a theoretical foundation in cognitive and neuropsychology. The primary criterion for inclusion of an item in either the Sequential- or Simultaneous-Processing Scales is how the stimuli are mentally manipulated, not the way the stimuli are presented to the child or how the child overtly responds.

The K-ABC was standardized on 2,000 children stratified on variables of sex, ethnic group (black, white, hispanic, other), geographic region, and community size. Test-retest reliability is reported by Kaufman and Kaufman (1983b, p. 83) for the 6-0 to 6-11 age range as .91 for Sequential Processing and .93 for Simultaneous Processing (reliability of a composite). Test-retest reliability coefficients (18 day span) for the age group 5-0 to 8-11 was .82 for Sequential Processing and .85 for Simultaneous Processing. The construct validity of the K-ABC was based on the results of factor analyses that support the existence of two mental processes of sequential and simultaneous processing. The concurrent validity of the K-ABC when compared with intelligence tests such as the Binet, WISC-R, and McCarthy was reported in the manual as ranging from .60 to .79.

Procedure

Eighty-four students (eligible subjects in first grade at time of testing) were group administered the California Achievement Tests

(Level 11, Form C) in September, 3 weeks after school started. The tests were administered by the first-grade classroom teachers as part of the requirements for assessment in the Tennessee Assessment of Basic Skills program and to meet local-plan requirements for the Chapter 1 (i.e., below-average achievement group) remedial program. The California Achievement Tests (CAI) were administered over a 3-day period with the reading tests given in one day. Teachers followed the group administration procedures as outlined by the publisher.

During October and the first week in November, 84 students were individually administered the mental processing scales on the Kaufman Assessment Battery for Children (K-ABC). Students were tested in random order from each of the five first-grade classrooms. Testing on the K-ABC was conducted by a certified school psychologist.

The students in this investigation received instruction during the school year (September through May) in reading as prescribed in the Holt Basic Reading System (Everetts et al., 1977). Use of the same instructional procedures as recommended in the Holt system by all teachers helped to assure a reasonable consistency between teachers in providing reading instruction. All teachers in the first grade evaluated student progress on objectives at the end of each instructional unit. Depending on each student's assessed level of mastery on each unit's objectives, supplemental instructional procedures were implemented by the teacher on the lesson(s) retaught to assure mastery of a minimum number of objectives.

Students in the Alcoa Elementary first grade begin reading instruction in the Holt Basic Reading System at Level 3. The Junior Primary class (i.e., a first-grade class for the developmentally delayed or below-average achievers) begins at Level 1. In this curriculum, the expectancy level is that an "average" first-grade student will master all reading skills through Level 7 in the system. The initial placement of students by teachers in class is based on performance levels in reading readiness skills assessed at the end of kindergarten. After an initial 4-week period in class, the teachers make adjustments in group placements if the students' progress in reading dictates that a change in instructional level is needed.

An interview with each of the first-grade teachers was conducted by the author during the second week of May. The purpose of the interviews was to review with each first-grade student's teacher the student's performance during the past year on the Holt Basic Reading System. The interviews included finding the level each student had reached in the reading program and a rating of classroom performance (i.e., independence in completion of classroom assignments).

During the second week in April, at the end of the school year, the first grade was administered Level 12, Form C of the California Achievement Tests (CAT). Procedures were the same as for the fall administration of the CAT.

Operational Definitions of Variables

The two independent variables in this investigation were assessed by the administration of the processing scales on the Kaufman Assessment Battery for Children (K-ABC) (Kaufman & Kaufman, 1983a). Sequential processing was defined as a standard score obtained by students on the Sequential-Processing Scale. The tasks on this processing scale require the student to respond to test items by placing components of information in serial order. Operationally, simultaneous processing was defined as a standard score measure obtained on the Simultaneous-Processing Scale. The tasks on this processing scale require the student to respond to test items by synthesizing components of information into a whole, integrated part.

For the purpose of this investigation, the higher or lower processing group refers to the criterion that there was at least 1 standard score difference in the processing-scale scores. When reference is made to deficient or nondeficient processing groups, the criterion was at or above a 90 standard score or below a 90 standard score, respectively, on the processing scales.

Where a reliance on either sequential or simultaneous processing was used to define groups, the criterion used was a significant difference between processing scores at a .05 level. For children in the 6-0 to 7-0 age range, this difference translates into a 12-point difference between scale scores.

Operationally, the dependent reading test variables in this investigation were defined by test scores obtained on the California

Achievement Tests (CAT) (Levels 11 and 12) (1979a). The variables were defined by standard scores, respectively, on the Phonic Analysis, Reading Vocabulary, and Reading Comprehension subtests. Total Reading on the CAT is a measure of overall reading ability. This score is obtained by numbering and weighing all CAT reading scores to arrive at a composite score. This is a separate score and not an averaging of all the reading scores.

Gain in reading skills was another dependent variable used in this investigation. This variable was operationally defined as a gain in reading skills from fall to spring during the school year. It was assessed by calculating the difference in fall and spring test scaled scores on the CAT reading tests. Scaled scores on the CAT were derived from an "equal-interval" scale that provides a standard score for each raw score value. The scaled scores provided a way to obtain a score that represents the number of skills learned by a student in relation to the total number to be mastered.

Classroom reading performance was operationally defined as the achievement of a student in the classroom on reading. This was assessed by interviewing each of the first-grade teachers. The interviews with the teachers provided information on how students achieved on the Holt Basic Reading System (Everetts et al., 1977) and their reliability in completing classroom assignments. The students in each designated classroom reading performance level met the following criteria:

1. The students at Level 1 had mastered at least 70% of the objectives in Level 7 and/or 8 in the Holt Basic Reading System. In

the classroom, the students consistently completed classroom assignments correctly with minimum commendation.

2. The students at Level 2 had mastered at least 70% of the objectives in Level 7 in the Holt Basic Reading System. In the classroom, the students consistently completed classroom assignments correctly but needed a moderate amount of feedback and structure to assure completion.

3. The students at Level 3 had mastered at least 70% of the objectives in Level 6 of the Holt Basic Reading System. In the classroom, the students were inconsistent in completion of their assignments and needed a lot of structure and frequent feedback to perform successfully.

4. The students at Level 4 had failed to master at least 70% of the objectives in Level 5 or above in the Holt Basic Reading System. In the classroom, the students were inconsistent in the completion of their assignments and needed a lot of structure and frequent feedback to perform successfully.

Data Reduction and Transformation

For purposes of this investigation, the raw scores and percentile rankings obtained from administration of the mental processing scales on the K-ABC and the reading tests on the CAT were converted to standard scores. The standard scores were calculated on a scale with a mean of 100 and a standard deviation of 15.

Gain scores were obtained by taking scaled scores obtained from the administration of the CAT spring and fall reading tests and calculating the differences between these scores. Scaled scores were calculated from an equal-interval scale to convert raw scores from CAT reading tests to a standard-incremental score.

Plan of Analysis

The proposed hypotheses in this investigation were tested in sequential order using analysis of variance (ANOVA) to determine statistical differences in mean scores between groups. The Scheffe's method of comparison was used as a follow-up procedure for making comparisons between individual groups whose differences in mean scores were analyzed with the ANOVA. Pearson product moment correlation coefficients and multiple correlation coefficients were calculated to determine the statistical relationships of scores within groups. Regression analysis was completed for the purpose of determining predictability of scores from one measure to another.

When the testing of the hypotheses called for use of ANOVA, the Mann-Whitney U or Kruskal-Wallis ANOVA tests were also performed. Results of these tests were compared with the ANOVA measures to determine if any inconsistencies in the data emerged because of differences between the K-ABC and CAT standardization samples and the children tested in this investigation. No inconsistencies were found between the parametric and nonparametric test results.

Consequently, only the parametric results have been reported from the hypothesis testing.

A chi-square analysis was used to determine the differences in expected frequencies between classroom reading performance levels in the number of students who relied more on one processing ability over the other. When the relationship between ordinal variables (i.e., reading achievement in the classroom) and the processing-abilities scales or total reading scores were examined, the eta correlation ratio was calculated to determine the relationships between variables.

The hypotheses in this study were tested at a .01 alpha level. This alpha level was used because of the large number of hypotheses tested. With eleven hypotheses, the probability of getting some random significance because of this is relatively high. Therefore, a stringent alpha level was used in an attempt to reduce Type 1 errors in the treatment of the hypotheses.

CHAPTER IV

RESULTS AND DISCUSSION

Student Score Distributions

The data obtained in this investigation from the administration of the Kaufman Assessment Battery for Children (K-ABC) and the reading tests on the California Achievement Tests (CAT) were used to calculate means and standard deviations for the scores of the first-grade students. The means and standard deviations were used to compare the students' score distributions in this study with the standardization samples of the K-ABC and CAT.

The California Achievement Tests (CAT)

Scores obtained from the fall and spring testing on the CAT reading tests were found to be clustered around the group mean. Mean scores for the Phonic Analysis, Reading Vocabulary, Reading Comprehension, and Total Reading were below those reported for the CAT standardization sample. Standard deviations for the scores on each reading test given in the fall and spring were calculated and found to be almost twice as large as those calculated for the CAT standardization sample.

The scores on the CAT in this investigation were not normally distributed. This may be the result of the criteria used for student selection. Mean scores on the CAT subtests were consistently below the standardization sample's mean scores (see Figures 3 and 4 and Tables 1 and 2).

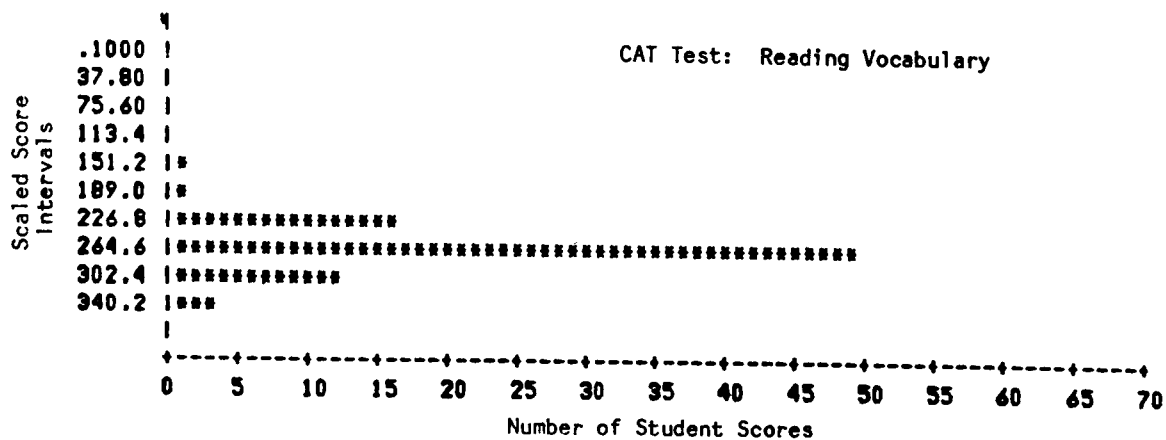
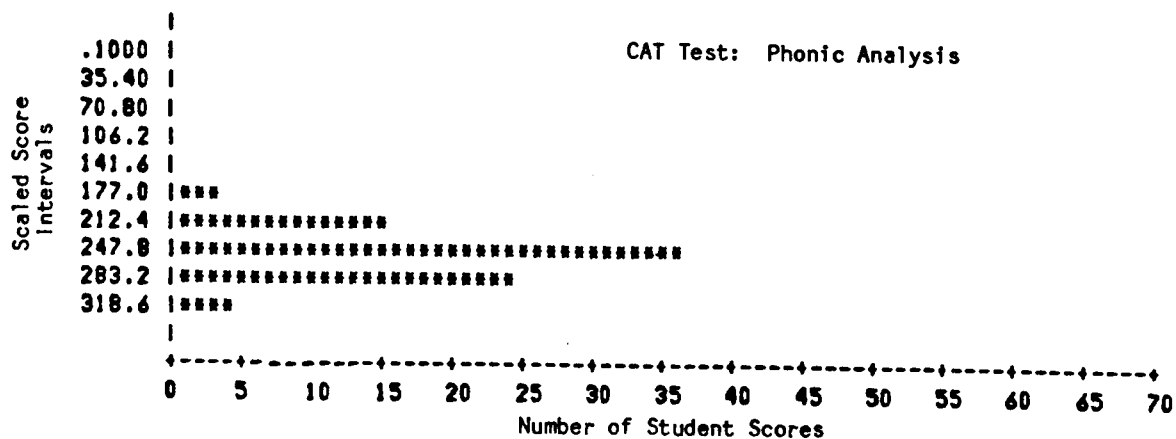


Figure 3. Score distributions for first-grade students, Fall testing, California Achievement Tests (CAT)--Reading Subtests.

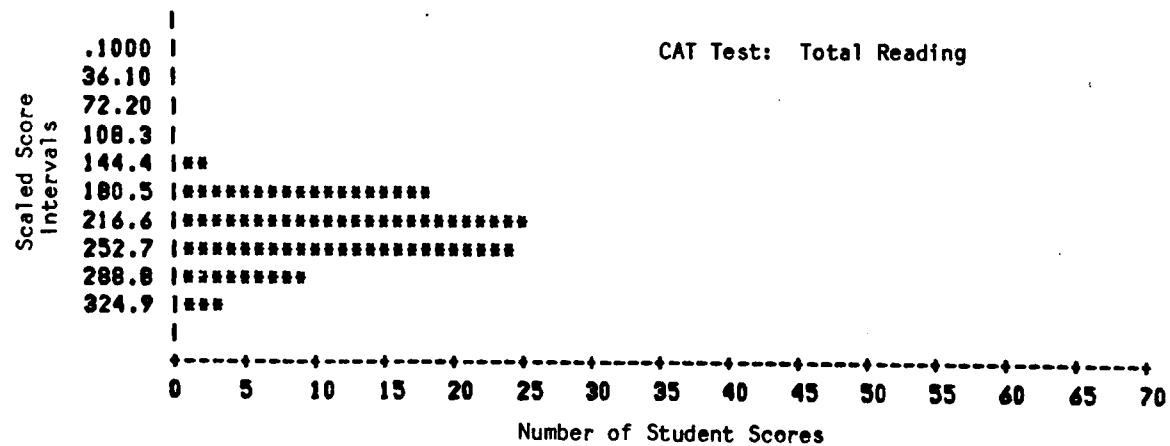
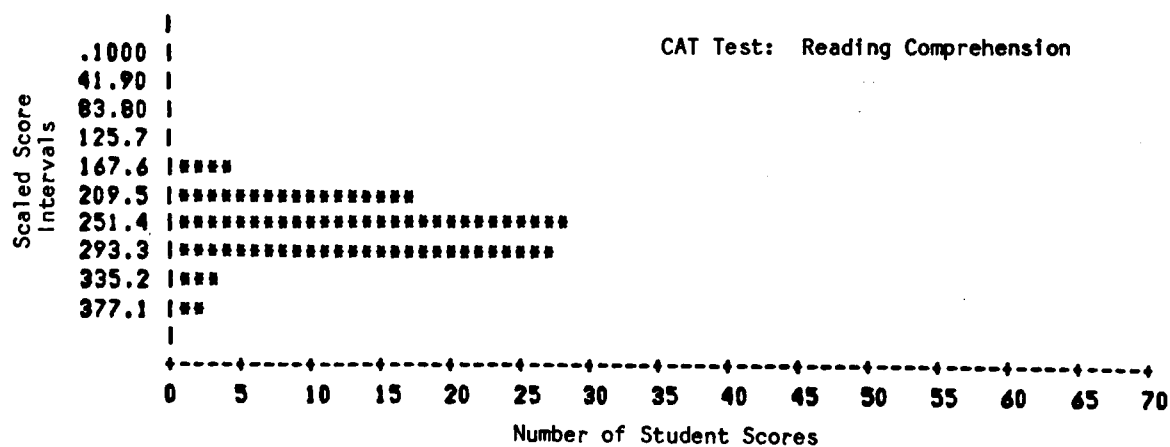


Figure 3 (continued)

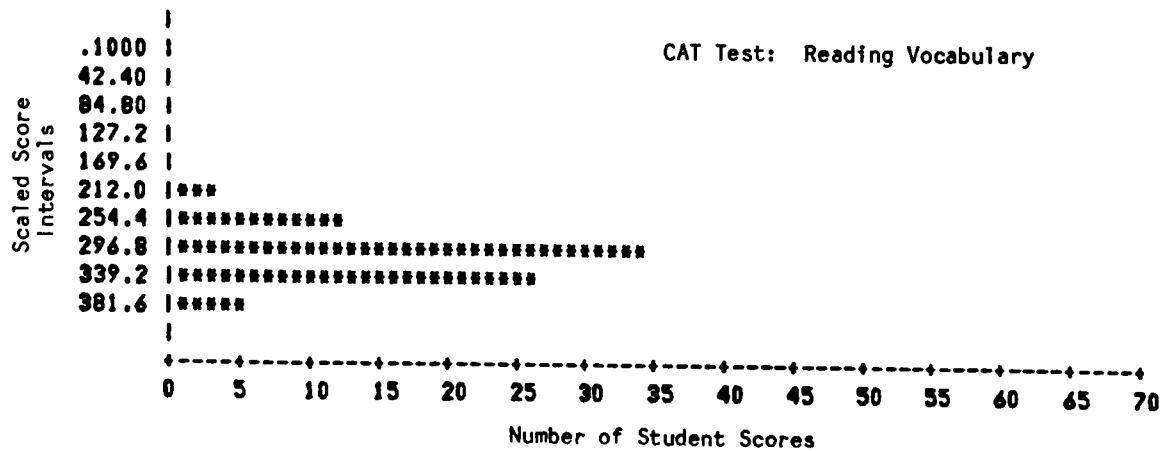
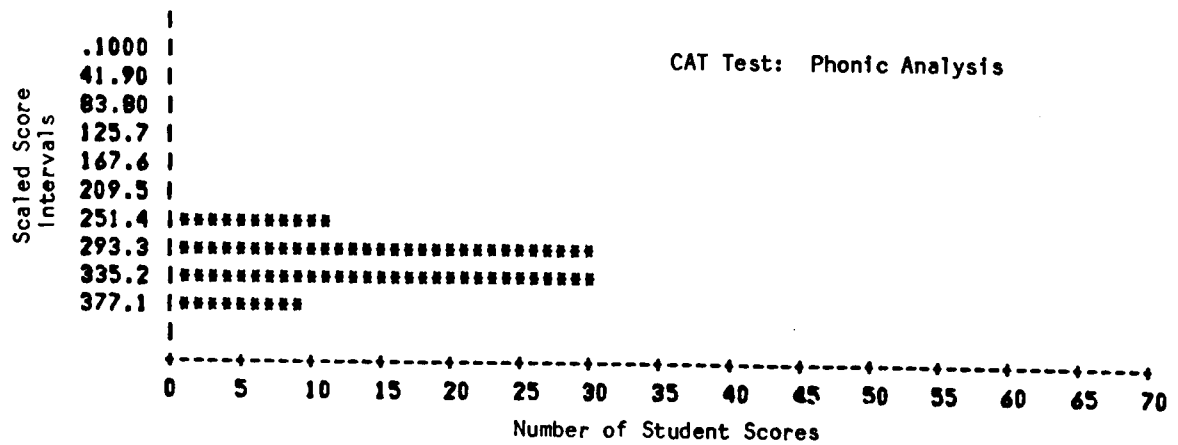


Figure 4. Score distributions for first-grade students, Spring testing, California Achievement Tests (CAT)--Reading Subtests.

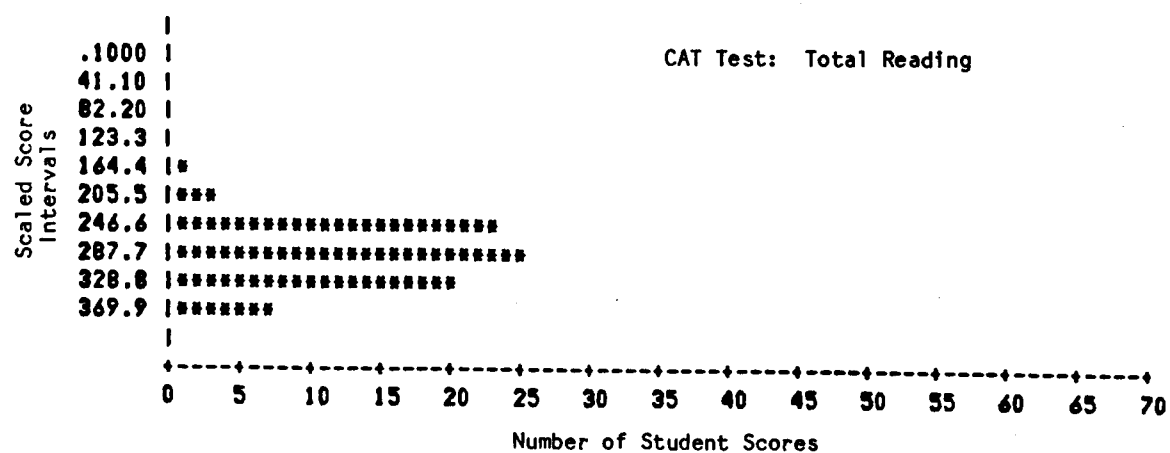
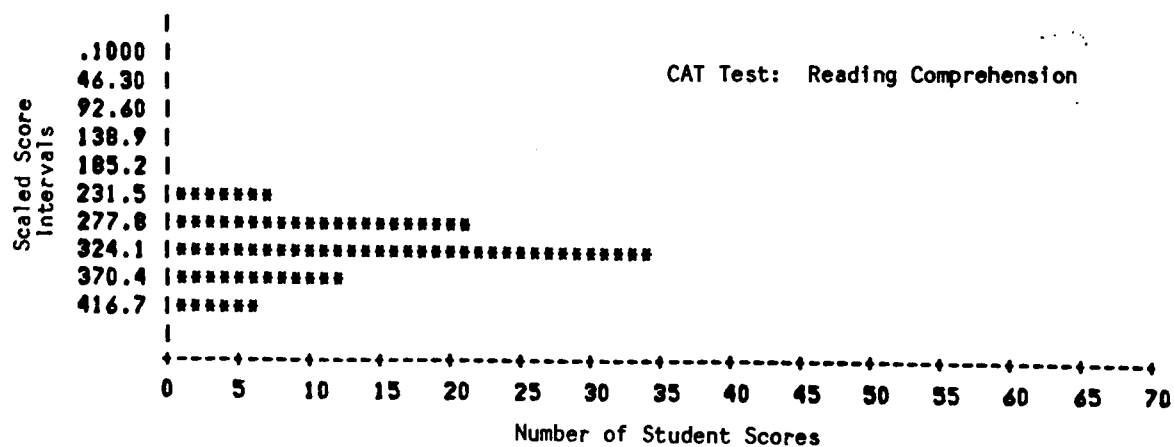


Figure 4 (continued)

Table 1

Comparison of the Standardization Sample's Fall Group Means with Study Sample's Fall Group Means on CAT, Level 11/C Reading Tests

Tests	Level 11/CAT C standardization sample ^a		Level 11/CAT C study sample ^b	
	Mean	SD	Mean	SD
Phonic Analysis	286	38	257	66
Reading Vocabulary	290	35	268	67
Reading Comprehension	386	43	262	78
Total Reading	266	38	232	69

Note. Group mean scores were calculated using CAT scale scores.

^a $\underline{n}$ = 3,500.

^b $\underline{n}$ = 84.

Table 2

Comparison of the Standardization Sample's Spring Group Means with Study Sample's Spring Group Means on CAT, Level 12/C Reading Tests

Tests	Level 12/CAT C standardization sample ^a		Level 12/CAT C study sample ^b	
	Mean	SD	Mean	SD
Phonic Analysis	332	48	310	92
Reading Vocabulary	334	42	308	93
Reading Comprehension	337	48	313	97
Total Reading	315	47	284	95

Note. Group mean scores were calculated using CAT scale scores.

^a $\underline{n} = 2,200.$

^b $\underline{n} = 84.$

The Kaufman Assessment Battery for Children (K-ABC)

Mean standard scores for the first-grade students obtained from the fall administration of the K-ABC were found to be slightly below the mean scores of the K-ABC standardization sample on the Sequential, Simultaneous, and Composite Processing Scales (see Table 3). The standard deviations calculated from the students' scores indicated there was very little range in ability levels among students. The score distributions for the K-ABC mental processing scales are represented graphically in Figure 5.

The scores on the K-ABC in this investigation were not normally distributed. Again, this may be the result of the criteria used for student selection in this investigation. The students also demonstrated a level of performance on the K-ABC that was below expectancies for their age. Mean scores on the K-ABC scales were consistently below the standardization sample's mean scores.

Hypothesis Testing

The Relationship of Sequential and Simultaneous Processing Skills to Reading Ability

Hypothesis 1. Test scores from the fall testing on the reading tests of the California Achievement Tests (CAT) and the mental processing tests on the Kaufman Assessment Battery for Children (K-ABC) were used to test the hypothesis that first grade students' entry level reading skills are related to their sequential- and simultaneous-processing abilities. Correlations among test scores on the CAT reading tests and sequential and simultaneous processing are

Table 3

Comparison of the Standardization Sample's and Study Sample's Mental Processing Standard Score Means and Standard Deviations on the K-ABC

K-ABC Mental Processing Scales	Standardization sample ^a		Study sample ^b	
	Mean	SD	Mean	SD
Sequential	101	15	95	19
Simultaneous	105	16	99	20
Composite	103	15	97	19

^aThe comparison was with that part of the standardization sample including students in the 6-0 through 6-11 age range. $\underline{n} = 200$.

^b $\underline{n} = 84$.

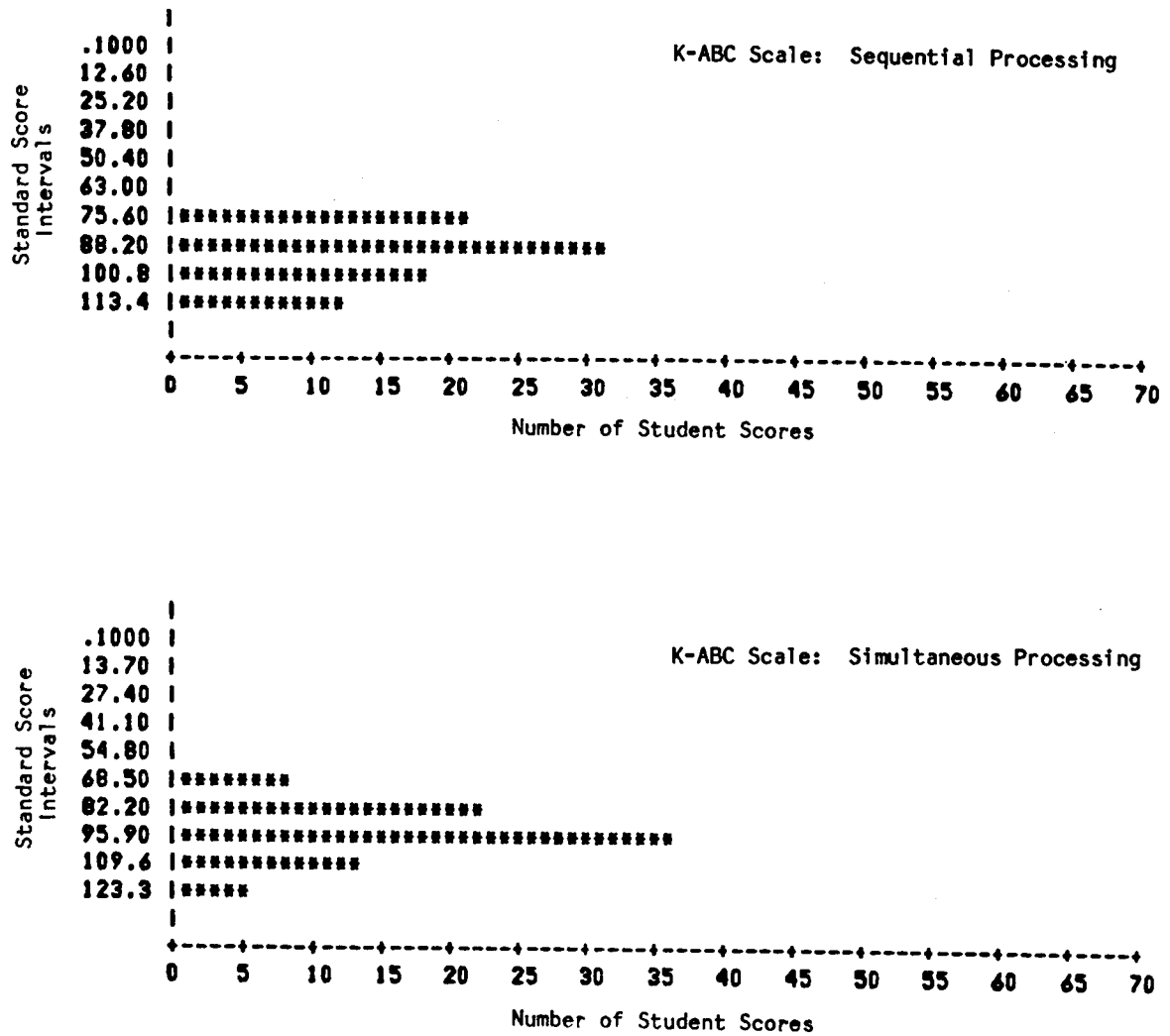


Figure 5. Score distributions for first-grade students on the Kaufman Assessment Battery for Children (K-ABC) processing scales.

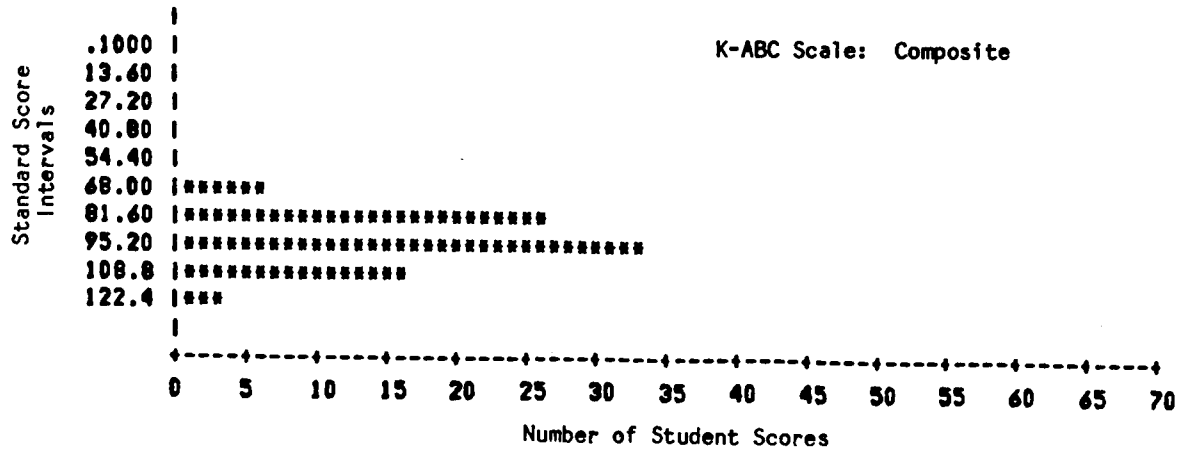


Figure 5 (continued)

Table 4

Pearson Product Moment Correlations of Entry-Level Reading Skills and Sequential- and Simultaneous-Processing Abilities

Reading skills tests	Processing abilities scales	
	Sequential	Simultaneous
Phonic Analysis	.55**	.55**
Reading Vocabulary	.54**	.46**
Reading Comprehension	.45**	.51**
Total Reading	.51**	.53**

Note. $n = 84$ for each correlation coefficient.

** $p < .01$.

shown in Table 4. The correlations of the fall reading-test scores with the sequential-processing test scores ranged from .46 to .55. The correlations of the fall reading test scores with the simultaneous-processing test scores ranged from .46 to .55. These correlations were all significant beyond the .01 level.

An additional analysis of the relationship between entry-level reading skills and sequential and simultaneous processing was conducted by performing multiple correlations. These results are summarized in Table 5. Together, Sequential- and Simultaneous-Processing Scale scores were calculated as accounting for between 27% and 34% of the variability in the reading test scores. All the multiple R_s were significant beyond the .01 level.

The use of individual and multiple correlation results provided some indication of the high comparability of the Sequential and Simultaneous factors in their statistical relationship to the reading test scores. For example, in correlations among scores on Phonic Analysis and the two processing scales, Sequential and Simultaneous Processing each accounted for 30% of the variance in students' test scores. A multiple correlation among the processing scale scores and Phonic Analysis showed an R^2 of .34. A similar pattern was evident for each of the other reading tests. Further analysis of these results showed that Sequential-Processing Scale scores had the strongest relationship with Phonic Analysis and Reading Vocabulary test scores. Simultaneous processing skills had the strongest relationship with Phonic Analysis, Reading Comprehension, and Total Reading scores.

The results of individual and multiple correlations in testing Hypothesis 1 permit the rejection of the null hypothesis. All

Table 5

Multiple Correlations for Sequential- and Simultaneous-Processing Abilities and Entry-Level Reading Skills

Processing abilities scales	Reading skills tests	$\underline{R}^2$	Multiple $\underline{R}$	$\underline{p}$
Sequential Simultaneous	Phonic Analysis	.34	.59	.001
Sequential Simultaneous	Reading Vocabulary	.30	.54	.001
Sequential Simultaneous	Reading Comprehension	.27	.52	.001
Sequential Simultaneous	Total Reading	.31	.55	.001

Note. $\underline{n} = 84$ for each multiple correlation.

correlations and multiple correlations between entry-level reading test scores and sequential- and simultaneous-processing factors were significant beyond the .01 level. These findings suggest a strong relationship between entry-level reading skills and a first-grade students' sequential- and simultaneous-processing abilities.

Hypothesis 2. Gain scores were used to test the hypothesis that first-grade students' progress in reading-skill development during the school year is related to assessed sequential- and simultaneous-processing abilities. Gain scores were obtained by calculating the differences in scaled scores between fall and spring reading tests on the CAT. These gain scores were correlated with standard scores on the K-ABC Sequential and Simultaneous Scales. The correlations among these scores are shown in Table 6. Gain scores in reading, as measured by the CAT reading tests, were not shown to have a high relationship to scores on either the Sequential or Simultaneous Scales of the K-ABC. None of the individual correlations among scores on the reading tests or processing scales was significant at the .01 level.

The relationship of gain scores in reading to processing abilities scores was analyzed further by the completion of multiple correlations. A summary of the multiple correlation results is provided in Table 7. It is suggested from these results that there is a slightly greater relationship of gain scores in reading to processing-abilities scale scores when Sequential and Simultaneous Scale scores are correlated together rather than correlated individually with each CAT reading test gain score. However, the relationship of those scores was not

Table 6

Pearson Product Moment Correlations of Gain Scores in Reading and Sequential- and Simultaneous-Processing Abilities

Gain scores on reading skills tests ^a	Processing abilities scales	
	Sequential	Simultaneous
Phonic Analysis	.23	.20
Reading Vocabulary	.26	.34**
Reading Comprehension	.27	.27
Total Reading	.28	.30**

Note. Gain scores were calculated on differences in scaled scores between pre- and posttest on CAT fall and spring reading tests.

^a $\underline{n} = 82$ for each correlation coefficient.

** $p < .01$.

Table 7

Multiple Correlations for Sequential- and Simultaneous-Processing Abilities and Gain Scores in Reading Skills

Processing abilities scales	Gain scores on reading skills tests	R^2	Multiple correlation	p
Sequential Simultaneous	Phonic Analysis	.06	.24	.09
Sequential Simultaneous	Reading Vocabulary	.11	.34	.01
Sequential Simultaneous	Reading Comprehension	.08	.29	.03
Sequential Simultaneous	Total Reading	.10	.31	.02

Note. $n = 82$ for each group.

strong enough to be significant at the .01 level. Together, the processing abilities only accounted for the variability in reading gain scores in a range from 6% to 11%.

The results of individual and multiple correlations in testing Hypothesis 2 support the null hypothesis. Gains in reading scores over the school year with first-grade students do not appear to have a strong relationship to their assessed sequential- and simultaneous-processing abilities.

Hypothesis 3. To test the hypothesis that first-grade students with lower classroom reading performance have lower assessed sequential- and simultaneous-processing abilities than students with higher classroom reading performance, an analysis of variance (ANOVA) was performed on the differences between selected reading achievement groups (Levels 1, 2, 3 and 4) in mean scores on the Sequential- and Simultaneous-Processing Scales of the K-ABC. The results of each ANOVA, summarized in Table 8, suggest a significant difference at the .01 level between classroom reading performance levels in both processing skills as measured by the K-ABC.

Additional analyses were performed on the differences in processing abilities between reading levels using the Scheffe's method of comparison. In Table 9 a summary of these results is provided. The results suggest that a difference between reading achievement groups in the first grade in sequential-processing ability was evident between Levels 1 and 3 and Levels 1 and 4. With regard to simultaneous-processing ability, the differences between reading levels was evident in the comparison of Levels 1 and 4.

Table 8

Analysis of Variance Summaries for Differences in Classroom Reading Achievement Levels in Sequential- and Simultaneous-Processing Abilities

Source	<u>df</u>	<u>SS</u>	<u>MS</u>	<u>F</u>	<u>p</u>
Sequential processing					
Between Groups	3	3,557.57	1,185.86	10.342	.0001
Within Groups	80	9,173.18	114.66		
Total	83	12,730.74	153.38		
Simultaneous processing					
Between Groups	3	2,821.33	940.45	6.494	.001
Within Groups	80	11,586.30	144.82		
Total	83	14,407.62	173.59		

Table 9

Summary of Scheffe's Method of Comparison Between Reading Achievement Levels on Sequential- and Simultaneous-Processing (K-ABC) Standard Scores

Comparison of reading achievement levels	<u>df</u>	Within levels variance estimate	<u>F</u>	<u>F'</u>
Sequential				
1, 2	43	2.09	4.37	12.87
1, 3	37	3.99	15.92	13.14**
1, 4	34	5.19	26.93	13.26**
2, 3	42	1.95	3.80	12.87
2, 4	39	3.34	11.16	13.02
3, 4	33	1.55	2.40	13.38
Simultaneous				
1, 2	43	2.33	5.43	12.87
1, 3	37	3.17	10.05	13.14
1, 4	34	4.03	16.24	13.26**
2, 3	42	0.75	0.56	12.87
2, 4	39	2.09	4.36	13.02
3, 4	33	1.54	2.37	13.38

Note. For any difference to be significant at the .01 level, F must be greater than or equal to F'.

** $p < .01$.

The ANOVA performed in testing this hypothesis does provide results that permit the rejection of the null hypothesis. In both sequential and simultaneous processing differences were found between reading groups at less than a .01 level of significance. These differences were further analyzed and found to be significant at the .01 level when comparing Levels 1 and 3, Levels 1 and 4 in sequential processing, and Levels 1 and 4 in simultaneous processing.

The Role of Sequential and Simultaneous Processing Skills as Prerequisites to the Development of Reading Skills

Hypothesis 4. Scores from the phonic skills test on the fall and spring administration of the CAT were used to test the hypothesis that students in the first grade with assessed sequential-processing ability higher than simultaneous-processing ability have higher scores on measures of phonics skills than those students with sequential ability equal to or lower than simultaneous ability. Testing the differences in the two cognitive processing groups on Phonic Analysis scores was performed using the t test. For the fall testing, no difference was found between the two groups in their Phonic Analysis scores, $t(23, 51) = 1.32$, $p < .20$. No difference between processing groups was also found for the spring testing of Phonic Analysis skills, $t(21, 54) = .02$, $p > .90$

The results of t tests for the fall and spring processing-group comparisons on phonic analysis scores did not permit rejection of the null hypothesis. These results show that first-grade students with stronger sequential-processing abilities than simultaneous-processing

abilities did not score better on measures of phonic skills than first-grade students with stronger simultaneous-processing abilities than sequential-processing abilities.

Hypothesis 5. Scores from the Reading Comprehension test on the fall and spring administration of the CAT were used to test the hypothesis that first-grade students with assessed simultaneous-processing ability higher than sequential-processing ability have higher scores on measures of reading comprehension than those students with simultaneous ability equal to or lower than sequential ability. The differences between the two designated processing groups on phonic-analysis scores was tested using the t test. For the fall testing, no differences were found between processing groups in Reading-Comprehension scores, $t(23, 55) = 1.32$, $p < .20$. This was also found to be the case with the spring testing, $t(23, 55) = 1.09$, $p = < .30$.

The results of t tests for the fall and spring processing-group comparisons on reading comprehension did not permit rejection of the null hypothesis. These results showed that first-grade students with stronger simultaneous-processing skills than sequential-processing skills did not score better on measures of reading comprehension than those students with stronger sequential-processing skills than simultaneous-processing skills.

Hypothesis 6. The hypothesis that students in first grade with deficient sequential-processing ability perform below students not deficient in sequential-processing ability in overall-reading achievement was tested using the t test. Results of the t test showed that there

was a difference between deficient and nondeficient sequential processing students in their Total Reading scores on the CAT, $t(25, 53) = 3.59$, $p < .001$.

The results of the t test for the difference in scores in Total Reading between deficient and nondeficient students in sequential processing permit the rejection of the null hypothesis. Hypothesis 6 was accepted with t -test results showing a high probability that students with deficient sequential-processing ability performed below nondeficient students in sequential ability on a measure of overall reading at the end of the school year.

Hypothesis 7. In testing the hypothesis that students in the first grade with deficient sequential-processing ability have less improvement in overall-reading skill during the school year than those students who do not have deficient sequential-processing ability, improvement in overall reading was determined by calculation of gain scores in Total Reading from scaled scores on the CAT. A modest difference in gain scores between the deficient and nondeficient sequential processing students was calculated on the CAT Total Reading scores, $t(23, 52) = 2.49$, $p. < .02$.

The differences in gain scores in Total Reading between the deficient and nondeficient sequential-processing students was not sufficient to meet the .01 criterion level required to reject the null hypothesis. It was not supported by the testing of Hypothesis 7 that students in the first grade with deficient sequential-processing ability have less improvement in overall reading than those with nondeficient sequential-processing ability.

The Effects of Relying Significantly More
on Sequential or Simultaneous Processing
in Reading

Hypothesis 8. In testing the hypothesis that first-grade students who rely more on either sequential or simultaneous processing in learning have less improvement in reading skills during the school year than those students with no difference between use of the two processing abilities, gain scores on each CAT reading test and Total Reading were used to determine reading improvement of the students. A series of t tests was calculated to determine differences in gain scores on the CAT reading tests between the two processing groups. A summary of those results is provided in Table 10.

The results obtained from testing Hypothesis 8 did not permit rejection of the null hypothesis. Students relying more on either sequential or simultaneous processing, as opposed to equal use of these abilities, did not show a difference in assessed reading score gains over the school year.

Hypothesis 9. The hypothesis that first-grade students who rely more on either sequential or simultaneous processing in learning perform at a lower level in the classroom in reading than those students with no difference between use of the two processing abilities was tested using a chi-square analysis. Reading levels were defined based on a continuum from above average to below average on the first-grade reading curriculum (see Chapter III). A summary of χ^2 calculations is provided in Table 11. It is suggested, based on these results, that there were no differences between classroom reading

Table 10

Summary of t tests on Differences in Gain Scores on CAT Reading Tests Between Students with Differential Processing Abilities and Those with Equal Processing Abilities

CAT tests used for reading gain scores	Students with differential processing ^a		Students with equal processing ^b		t	p
	<u>M</u>	<u>SD</u>	<u>M</u>	<u>SD</u>		
Phonic Analysis	59.87	38.90	57.83	31.57	.25	.65
Reading Vocabulary	54.57	44.12	47.74	35.33	.71	.40
Reading Comprehension	63.30	51.63	54.76	46.62	.74	.40
Total Reading	62.47	47.74	62.00	42.93	.04	.85

Note. The means for students are presented in gain scores.

^aStudents with differential processing had differences in Sequential and Simultaneous Processing Scores on the K-ABC at the .05 alpha level. $n = 30$.

^bStudents with equal processing had no differences in Sequential and Simultaneous Processing Scores on the K-ABC at the .05 alpha level. $n = 46$.

Table 11

Summary of χ^2 Calculations for the Relationship Between Reading Achievement Levels and Reliance on Either Sequential or Simultaneous Processing

Reading levels compared	<u>n</u>	χ^2	<u>p</u>
1, 2	47	5.43	.02
1, 3	41	1.48	.22
1, 4	38	3.50	.06
2, 3	46	1.24	.26
2, 4	43	0.10	.74
3, 4	37	0.50	.49
5, 6	84	0.27	.61

Note. Level 1 = above average/high average classroom achievement;
 Level 2 = high average to average classroom achievement;
 Level 3 = average to low average classroom achievement;
 Level 4 = below average classroom achievement;
 Level 5 = the combination of Levels 1 and 2;
 Level 6 = the combination of Levels 3 and 4.

achievement levels with respect to the number of students who relied primarily on either sequential or simultaneous processing.

The chi-square analysis conducted on Hypothesis 9 did not produce results that permitted rejection of the null hypothesis. Consequently, Hypothesis 9 was rejected. Reliance on one processing ability over the other was not shown to relate to the students' achievement level in reading in the classroom.

The Comparison of Processing Skills and
Reading-Achievement Scores in Predicting
End-of-the-Year Reading Level

Hypothesis 10. The hypothesis that measures of sequential- and simultaneous-processing ability predict better than grade-entry measures of reading ability the end-of-the-year reading level of first-grade students was tested using scores from the fall administration of the Sequential- and Simultaneous-Processing Scales of the K-ABC and the fall reading tests of the CAT. These scores were correlated with reading achievement scores obtained from the spring administration of the CAT.

The first procedure completed in testing Hypothesis 10 involved the comparison of correlation coefficients of the predictor measures with the end-of-the-year (spring) reading test scores on the CAT. The predictor measures included the scores on the two processing-abilities scales on the K-ABC and the fall reading test scores on the CAT. The fall predictor reading test scores from the CAT correlated significantly with only their corresponding reading test scores on the spring CAT (e.g., phonic analysis with phonic analysis). In

Table 12 a summary is provided of Fisher's z_r transformations for determining the significance of the difference between correlations of the predictor variables (i.e., processing scale scores and fall CAT reading scores) with end-of-the-year (spring) CAT reading scores.

Results of the correlations between the predictor variables and end-of-the-year (spring) reading test scores support the suggestion that the Sequential- and Simultaneous-Processing Scale scores accounted for more of the variance in CAT spring reading test scores than did the CAT fall reading test scores. However, Fisher's z_r tests did not show differences in correlations between processing ability and reading test predictors to be significant at the .01 criterion level.

The tests used in testing Hypothesis 10 did not show sufficient differences in predictability between the processing scale scores and fall reading test scores to reject the null hypothesis. Hypothesis 10 was rejected, with the current data supporting the position that entry-level reading tests of reading achievement do predict as well as sequential- and simultaneous-processing measures on end-of-the-year reading achievement test levels.

Hypothesis 11. In testing the hypothesis that measures of sequential- and simultaneous-processing ability predict better than grade-entry total reading scores the performance levels achieved in the reading curriculum by first-grade students, the relationship of students' reading-achievement level (i.e., Levels 1, 2, 3 and 4) to processing ability scores on the K-ABC and CAT (fall) Total Reading

Table 12

Summary of Fisher's z_r Transformations for Significance of the Difference Between Correlations of End-of-the-Year Reading Scores with Processing Abilities and Grade-Entry Reading Scores

End-of-the-year reading tests (spring)	Grade entry predictor tests (fall)	r^a	z	p
Phonic Analysis	Sequential Phonic Analysis	.57 .40	1.76	.10
Reading Vocabulary	Sequential Reading Vocabulary	.61 .39	2.20	.05
Reading Comprehension	Sequential Reading Comprehension	.57 .36	2.15	.05
Total Reading	Sequential Total Reading	.58 .40	1.99	.05
Phonic Analysis	Simultaneous Phonic Analysis	.54 .40	1.55	.20
Reading Vocabulary	Simultaneous Reading Vocabulary	.55 .39	1.66	.10
Reading Comprehension	Simultaneous Reading Comprehension	.53 .36	1.82	.10
Total Reading	Simultaneous Total Reading	.56 .40	1.78	.10

Note. $n = 82$ for each correlation coefficient. All correlation coefficients significant at .01 level. Fisher's z_r was used to test for significance of difference between correlations.

was investigated. The correlation ratio (η) was used to measure the relationship between the predictor variable scores (i.e., Sequential, Simultaneous, and Total Reading) and reading achievement levels.

In Table 13 a summary is provided of correlation ratios performed with the three predictor variables. All three predictor variables had a significant relationship to the first-grade students' reading achievement level in the classroom. Of the two processing abilities, Simultaneous scores were shown as having the strongest relationship to achievement levels in the reading curriculum. Total Reading scores from the fall administration of the CAT were found to be about equal to Sequential-Processing Scale scores in predicting reading achievement level of first-grade students in the classroom. The Composite scores from the Sequential- and Simultaneous-Processing Scales were used to test the relationship of the combined processing abilities to classroom reading achievement level. As shown in Table 13, the composite of the processing-ability scores was related to reading achievement level with almost the same coefficient and variance as the fall Total Reading scores.

Results from the completion of the correlation ratios did not permit rejection of the null hypothesis. Although Simultaneous Processing was calculated as being a stronger predictor than Total Reading, the Composite Sequential and Simultaneous scores were not indicated as having a stronger relationship to reading achievement level than fall Total Reading scores. Consequently, Hypothesis 11 was rejected.

Table 13

Correlation Ratios for Relationship of Processing Abilities and Total Reading Achievement to Classroom Reading Performance Levels

Predictor variables	Eta	<u>F</u>	<u>p</u>
Sequential Processing	.52	9.74	.001
Simultaneous Processing	.70	26.33	.001
Composite Processing	.56	12.04	.001
Total Reading	.57	12.36	.001

Note. The processing variables (i.e., Sequential, Simultaneous, and Composite) and Total Reading were used to predict student performance level in reading in the classroom (Levels 1, 2, 3 or 4). The degrees of freedom (df) for each correlation ratio were 3 for between groups and 80 for within groups.

Synthesis of Results

Eleven hypotheses, grouped under four areas of study, regarding the relationship between assessed sequential and simultaneous processing and reading performance in the first grade were tested in this study. A synthesis of the results obtained from the testing of the hypotheses is provided in this section.

1. A relationship between sequential- and simultaneous-processing abilities and reading performance (i.e., on tests and in the classroom) was moderately supported. Each processing skill was correlated significantly with each reading subtest. However, the multiple correlations of both processing scores with reading performance measures only accounted for a slightly greater percentage of variability in the dependent reading variables. It appears that both sequential and simultaneous processing contribute to reading achievement for first graders. Sequential- and simultaneous-processing scores were found to relate minimally to gain scores in reading achievement. The processing scores accounted individually for 5% to 6% of the variance in reading gain scores. Combined, the processing factors accounted for only 8% to 11% of the variance in students' reading score gains. In terms of classroom performance, it was suggested that sequential- and simultaneous-processing abilities are related to individual students' classroom reading achievement at the end of the school year (i.e., Levels 1, 2, 3, and 4). The higher the scores on both processing scales, the stronger their relationship was

to classroom performance during the school year on the reading curriculum.

2. It was not supported that superiority in one processing ability over the other had a differential relationship to reading skill development. With first-grade students, it does appear that stronger or weaker sequential or simultaneous processing may be related to how a student does on particular reading subskills (e.g., phonic analysis, reading comprehension). Although students with deficiencies in sequential processing (<90 standard score) were found to have lower reading achievement than other students, it was found that these same students were usually deficient in simultaneous processing (<90 standard score) as well.

3. First-grade students who have significant differences (.05 alpha) between sequential- and simultaneous-processing ability were not found to be different from students with equal processing abilities in achievement test reading score gains over the school year. It was also determined that first-grade students with a significant difference between processing-ability scores were not on a lower reading level in the classroom curriculum with any more frequency than students who did not have a discrepancy in processing scores.

4. The results of this study did support the use of sequential- and simultaneous-processing factors as predictors of reading achievement for first-grade students. It is suggested that for beginning readers, the scores on the K-ABC Sequential- and Simultaneous-Processing Scales are at least equal to grade-entry

reading achievement tests in predicting spring reading achievement scores. The equality of processing scores in predicting reading achievement was also evident in testing their relationship to classroom reading achievement level. The composite scores of sequential and simultaneous processing were found to be equal to entry-level Total Reading scores in predicting end-of-the-year Total Reading achievement scores.

CHAPTER V

CONCLUSION

Discussion

The findings of this current investigation lead to several major conclusions about the relationship of sequential- and simultaneous-processing abilities to the reading skill development of first-grade students. First, it is apparent that the cognitive information processing abilities, as measured by the K-ABC, are related to reading achievement. The correlations calculated between the two processing factors and reading subskills are consistent with those reported by Kaufman and Kaufman (1983b). The significant differences found in sequential and simultaneous processing between achievement groups was also found with older subjects in studies by Krywaniuk (1974), Shade (1983), and Merritt and McCallum (1984).

The fact that correlations of the CAT reading subtests with the K-ABC processing scales are comparable with previously reported intelligence test-achievement correlations (Sattler, 1982) supports a general (g) factor of intelligence operating on the mental processing scales. That a g factor of intelligence is measured by the K-ABC mental processing scales is further supported by the fact that high- and low-achievement groups scored high and low, respectively, on the two processing scales. In addition, multiple correlations showed that a composite of the two processing factors only increased the variability accounted for in reading scores by a small percentage. These results

support the idea that the two processing scales may have considerable overlap in the intelligence construct they measure. The findings that a common g factor is measured by both processing scales support Kaufman and Kaufman's (1983b) assertion that the K-ABC mental processing scales are measures of intelligence, as well as of sequential- and simultaneous-coding skills.

A second conclusion drawn from the results of this investigation is that there is not sufficient evidence to verify the operational differences between the two processing skills on individual reading subtests. No support was provided from the research for concluding that either coding skill was more effective than the other in handling a particular reading task. This finding is in conflict with reported studies (e.g., Cummins & Das, 1980; Ehri & Wilce, 1985; Stanovich et al., 1984a) from which it was suggested that decoding and other earlier acquired reading skills are primarily dependent on sequential processing and that fluent reading relies primarily on simultaneous processing.

It was not indicated in the current investigation that a significant difference existed between classroom achievement groups in the use of sequential- or simultaneous-processing skills. This result was supported by Nesterak and Ferrari (1986) in their study with elementary students and Merritt and McCallum (1984) in their study with college students. In both studies the authors suggested that sequential- and simultaneous-processing scores were not significantly correlated with classroom achievement. As Chatman et al.

(1983) found with the K-ABC standardization sample, the first-graders in the current study exhibited discrepancies within achievement groups in sequential and simultaneous processing. These discrepancies have been found to be common and most likely reflect individual differences in information-processing style and learning experiences.

The third major conclusion drawn from the research is that measures of sequential and simultaneous processing may be equal to or better predictors of reading test achievement than first-grade entry-level reading achievement tests. This conclusion may be only relevant for preschool or beginning reading groups. Although the current results did not indicate a difference in processing abilities and entry-level reading tests in predicting spring reading test scores, the resulting comparability between the cognitive and achievement variables in prediction is contrary to the results of similar research. For example, Childers et al. (1985) found the K-ABC Achievement Scale a better predictor of CAT Total Reading than the K-ABC Sequential- and Simultaneous-Processing Scales.

There are several possible reasons for the increased predictability of the information-processing measures found in this current investigation. It may be that the entry-level CAT reading tests are more reflective of cognitive and/or perceptual skills than actual reading processes. If this is the case, then the K-ABC scales given in the fall may be good measures of the information processing required on the CAT reading tests administered in the spring. It is also likely that the results from the current investigation differed

from other studies because of the homogeneous nature of the sample used in this investigation. Prediction studies reported in the literature most often included students from across grade levels and age ranges. Differences in results on prediction of reading test scores from processing-ability measures may be because of critical differences in test-retest reliability. Although a study of the item content on the fall and spring CAT reading tests verified the comparable content of the forms, it was found that the first-graders in this investigation had lower test-retest reliability coefficients between the two forms of the CAT than reported for the CAT standardization sample (see Table 3, p. 90). Again, this may be because of the smaller and less heterogeneous sample used in the current investigation. Nevertheless, it is suggested that the data generated here on prediction may be peculiar to the subjects in this investigation.

The developmental factor should also be considered in the prediction of the reading scores from K-ABC mental processing scores at a 7-month interval. It is possible that the first-grade students change their use of either sequential or simultaneous processing for the same type reading task over time. This phenomenon is supported by Das et al. (1979) from their research and Kaufman and Kaufman's (1983b) findings during the development of test items on the K-ABC. Factor loadings in the above research supported the idea that it was the nature of the task demand that influenced the process used, not the content of the stimulus or type of response. Kaufman et al.

(1982) and Kaufman and Kamphaus (1984) confirmed the developmental changes in children's use of processing skills that take place with problem-solving tasks on the K-ABC. Although there are exceptions, young children as a group appear to alternate sequential- and simultaneous-processing preferences with the same tasks as they get older. Applied to reading, this may mean that at the beginning stages of learning, sequential processing is used for more auditory/memory tasks. As skills become more "automatic," the child then may use sequential processing for analytical/deductive thinking and language usage. In a like manner, simultaneous processing may be used in beginning reading by children to handle basic letter-recognition (visual perception) tasks and later to process sight words and integrate information for reading comprehension.

Limitations

The failure of the current investigation to support hypotheses concerning the operational differences in the relationship of sequential and simultaneous processing to reading performance may have been because of several factors:

1. The design of this investigation was ex post facto research in which an experimental manipulation of the variables was not possible. Thus, the internal validity of the study may be questioned because the relationship of external variables to the dependent measures in reading was unknown.

2. The unique relationships between the dependent and independent variables in this study may have been masked by the problem of multicollinearity. Multicollinearity refers to the highly redundant associations the independent variables have with the various dependent variables. When independent variables are highly associated with each other, the correlation coefficients obtained in a simultaneous model are often misleading. In the current investigation, sequential and simultaneous processing were highly correlated (.74 coefficient).

3. The subject selection in this investigation was limited to children enrolled in the first grade who were not repeating the first grade and who were not identified as handicapped. The sampling criteria may have served to provide insufficient variability among first-grade students in the variable measures. This could have affected the discrimination power of the testing procedures. Students in this study had relatively high standard deviations in their test-score distributions. This fact, along with the fact that only 27 of 84 students tested on the K-ABC had significant differences between scores on the Sequential and Simultaneous Scales, provided little opportunity to compare levels of reading performance to differences in processing skills.

4. Finally, failure to establish a differential cognitive processing-reading skill relationship may mean there are theoretical deficiencies. The sequential and simultaneous processes measured by the K-ABC may not account for the unique approaches by each child to the reading process. This, in turn, may have caused a failure in

assessing any specific pattern of response that may be found in children with different cognitive processing abilities. It has been demonstrated that the K-ABC does provide an adequate measure of general intelligence. However, because its processing scales are not "pure" measures of sequential and simultaneous processing, they may not provide sensitive enough measures of the actual mental operations that take place in what Das et al. (1979) call the "central processing" component of information processing.

It may be that the significance of levels of sequential- and simultaneous-processing skills is only important for those children who have specific handicaps or learning disabilities. In normal children, the acquisition of skills in letter recognition, decoding, and comprehension may not be related primarily to sequential- or simultaneous-processing abilities. For example, a student with relatively stronger sequential than simultaneous skills may learn to read whole words as well as a student with the opposite strengths. As long as there is some interaction of the processing abilities, the students in either group may be able to master each type of reading skill with equal efficiency.

Implications

The results of the current research have some important implications for how reading skill development in first-grade students is perceived. Sequential- and simultaneous-processing abilities, as measured by the K-ABC, were found to be correlated significantly

with reading achievement in the first grade. It is debatable, however, as to whether or not a g factor of intelligence or the specific processing skills affect the variance in reading achievement. It must also be argued that the relationship between processing abilities and reading achievement has been primarily established only in terms of test scores. The relationships between variables then might be a methods artifact rather than an actual functional relationship. Nevertheless, the factor analytic studies of the K-ABC do support the construct validity of sequential- and simultaneous-processing factors. Consequently, it would appear that, given the theoretical support for the processing skills, it is prudent to address them as operational variables in the reading process. This provides an advantage, as Wagner and Sternberg (1984) asserted, in relating underlying cognitive processes to the act of reading.

Gains in reading performance were not found to be appreciably related to the two processing skills. This fact, along with the failure of the measures to discriminate operational differences in sequential and simultaneous processing on reading, supports the need for frequent evaluation of first-grade students in their reading and cognitive development. Periodic evaluations would help to account for the developmental factors (age and experience) that have been shown to influence change in emphasis on the use of either coding skill in reading tasks. It may be that the failure to find differential sequential- and simultaneous-factor relationships in the current investigation was because testing was done only at the beginning and

ending of the school year. If the reading models previously discussed (LaBerge & Samuels, 1974; Perfetti & Roth, 1981; Taylor & Taylor, 1983) are accurate representations of the interchange between cognitive-information processing and reading, then frequent individual evaluations are likely to be necessary to determine the students' evolving use of each coding skill. Furthermore, it is probable that group data involving students who are at varying levels of development tend to mask the individual variance in scores accounted for by either sequential- or simultaneous-processing factors.

Data from the research also support the idea that for normal first graders, sequential- and simultaneous-coding skills are both necessary to the reading process. Thus, it appears that the ability to use both processing modes, as required by task demands, is the optimal condition for progress in reading skill development. This conclusion was also reached by Das et al. (1975, 1979) and supported by Taylor and Taylor (1983) in their use of Bilateral Cooperative Reading Model. It is possible that the differential effects of sequential and simultaneous processing only apply to students with extreme deficiencies in learning skills. This idea was suggested in studies by Harness, Epstein, and Gordon (1984) and Hooper and Hynd (1986), where it was shown that student use of one processing mode over another caused inefficiency and inflexibility in responding to different task demands in reading.

Confirmation of this phenomenon would have implications for teachers who are involved in reading-remediation activities. If it is

observed that a student is extremely deficient in some reading skills and is overly reliant on one processing mode, then a strengths model of remediation may be preferable. The matching of educational treatments to mental processing strengths has received modest support from several research investigations (Biggs, 1978; Gunnison & Kaufman, 1982; Hartlage, 1975; Reynolds, 1981).

Using measures of cognitive-information processing to predict more precisely later reading achievement has important implications for developing curriculum and instructional procedures for beginning readers. The identification of high-risk children with below average or limited language skill development can be enhanced using the more "fluid" measures of intelligence characterized by sequential- and simultaneous-processing factors. Readiness tests in reading are normally given in kindergarten and first grade at the beginning of the school year. It appears that performances on the processing scales may be as reflective of actual potential in reading skill development as are performance on the reading skill tests. Too much dependency on language development and other performance variables can reduce the predictability coefficient of early reading skill measures for many children.

A more precise prediction of reading achievement, with the validity less affected by experiential and behavioral variables, would be a valuable tool for teachers trying to assure that beginning readers make consistent progress in their skill development. Normal children could be taught the effective use of both processing skills with each

level of task demands. Children with learning problems, or those at risk for slow development, could be identified earlier and appropriately included in strength-remediation programs.

In conclusion, it is evident that if the quest for a verifiable relationship between processing skills and reading performance is to be completed, more research is needed. The current investigation makes a contribution to ATI research in that it provides an analysis of processing skill-reading performance interaction with a specific population (i.e., grade and age). This is in contrast to earlier reported studies in which scores of subjects from different age groups and grade levels were combined. The analysis of independent-variable accountability using a heterogenous sample makes it difficult to isolate effects at each developmental stage. This is an important consideration because of the fact that a child's developmental level in thinking and problem-solving has been shown to influence greatly the use of sequential- and simultaneous-processing skills to meet task demands.

Given the fact that the interaction of information-processing skills and reading ability is a complex one, it is recommended that future research in this area include a design that helps to account for more of the variables in reading skill development. This might include an analysis with covariates such as language functioning, general level of intelligence, and developmental factors. It is also recommended that further research include use of psychometric measures of the sequential and simultaneous factors other than standardized tests. It

appears that the results from the K-ABC scales may have been compromised by variables affecting the required input and output responses. Consequently, the assessment of "central processing" abilities, including sequential and simultaneous processing, may not be valid. A clinical neuropsychological approach might provide additional information that would provide a more valid assessment of processing skills used on a regular basis by an individual. This approach includes looking at developmental milestones, carrying out naturalistic observation, and using multiple measures of neuropsychological functioning. These kinds of procedures are necessary if educators and cognitive theorists are to go beyond the realm of prediction and establish cognitive measures that have direct application to the instructional process.

There are no guarantees that the recent conceptions of intelligence as information processing will be more consequential to education than past conceptions. The research presented here does contribute to the understanding of the difficulty in deriving implications for education from cognitive theory. Individual uniqueness of neuropsychological functioning may make it very difficult to use group data to make generalizations about brain-behavior relationships in learning.

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VITA

James Michael Carrig was born in Corry, Pennsylvania, on July 7, 1947. He attended elementary school in that city and was graduated from Corry Area High School in June 1965. The following September he entered Edinboro University of Pennsylvania, and in June 1969 he received a Bachelor of Arts degree in psychology. In the summer of 1969 he began study towards a master's degree in educational psychology at Edinboro University. This degree was awarded in August 1970.

After a 22-month tour of duty with the United States Army, including 11½ months in Vietnam, he entered the School Psychology Specialist Certification program at Edinboro University, in September 1972. He graduated with a Specialist Certificate in School Psychology in May 1973.

Following graduation, he worked one year with the Northwest Tri-County Intermediate Unit in Erie, Pennsylvania, as a school psychologist. The next year he accepted a position in Tennessee as Coordinator of Psychological Services with the Clinch-Powell Educational Cooperative in Tazewell, Tennessee. Two years later, he took a position with the Little Tennessee Valley Educational Cooperative, serving as a school psychologist for the Blount County School system. In the fall of 1978, he was hired by the Alcoa City Schools, Alcoa, Tennessee, to provide school psychological services and help coordinate the implementation of the special education program.

In the winter of 1981, Mr. Carrig entered the Ph.D. program in Education at The University of Tennessee, Knoxville. He received the Doctor of Philosophy degree, with an emphasis in Theories and Practice of Educational and Personal Adjustment, in June 1987.

Mr. Carrig is a member of Phi Kappa Phi, The Tennessee Association of School Psychologists, The National Association of School Psychologists, International Association of Pupil Personnel Workers, and the East Tennessee Coalition for Children. He has recently served on the Child Abuse Council and is currently on the Board of Directors for Parents Anonymous in Blount County, Tennessee.

He is married to the former Suzanne Dixon of Hendersonville, Tennessee, and has a stepdaughter, Jennifer, and a daughter, Lauren.