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# READING ACQUISITION: COMPARING THE LONG TERM IMPACT OF EARLY INTERVENTION PROGRAMS USING LISREL MODELS WITH STRUCTURED MEANS

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# READING ACQUISITION: COMPARING THE LONG TERM IMPACT OF EARLY INTERVENTION PROGRAMS USING LISREL MODELS WITH STRUCTURED MEANS

by

Andrew C. Leon

A dissertation submitted to the Graduate Faculty in
Educational Psychology in partial fulfillment of the
requirements for the degree of Doctor of Philosophy,
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# Abstract

## Reading Acquisition: Comparing the Long Term Impact of Early Intervention Programs Using LISREL Models with Structured Means

by

Andrew C. Leon

Advisor: Professor David Rindskopf

Two general approaches to compensatory education are used to minimize the number of children who are inadequately prepared for reading instruction. One is used to augment skills deficits. The other works less directly; it is designed to serve those considered at risk on the basis of their socio-economic status (SES). The objectives of this study parallel those approaches. First, the causal relationships among reading readiness and reading achievement abilities were examined in structural equation models of reading acquisition. Second, Head Start and No Preschool samples were compared on SES and reading achievement constructs using structural equation models with structured means.

The data came from the Longitudinal Study of Disadvantaged Children and their First School Experiences, a joint project of the Educational Testing Service and the Head Start Research Office. Five models of reading acquisition were tested. The observed variables were multiple observed measures of each construct, administered from one year prior to preschool through the third grade. Causal relationships among latent constructs of home background, pre-readiness, reading readiness, and reading achievement were hypothesized and tested in the models. The findings support the literature: there are reading readiness skills which facilitate reading achievement. Readiness assessment is shown to be valuable in accounting for individual differences in reading achievement.

One model compared the reading achievement of Head Start and No Preschool samples after controlling for SES differences. Head Start was shown to have no effect on achievement at a given level of SES. This result was compared with that of a more commonly used technique, analysis of covariance. In the latter analysis the groups were not compared using latent variables as in the other analyses, but instead using observed variables. In that analysis, Head Start was shown to have a detrimental effect. This finding appears to contradict that of the other analyses. Reasons for this difference are considered and advantages and disadvantages of the statistical techniques are discussed.

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The children who were my reading students inadvertently demanded that I ask the question: How does a child become an independent reader?

The data base was a pivotal element of this study. I thank Bliss Siman of Baruch College for assistance in my search for data. Many people at Educational Testing Service assisted in making the database available: J. Brooks-Gunn, Sam Messick, Don Rock, Virginia Shipman, Norma Norris, and Rosemary Deibler.

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My wife, Yukiko Okuma, always shared her love and support.

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# CHAPTER 1

# INTRODUCTION

Reading is an essential tool in our literate society. Many children become facile readers with no apparent problem. For others, mastery of basic reading skills is difficult. For some, it is never accomplished. The frustration of reading failure can be the result of an untimely beginning of formal reading instruction. A child's initial exposure to formal instruction is usually dictated by his or her age and the specific policy of the school in which the child is enrolled. In order to minimize the number of children who are inadequately prepared for reading instruction, two general approaches to compensatory education are employed. One is based on augmenting skills deficits. The other works more indirectly by attempting to ameliorate cultural disadvantage.

In the first approach schools determine the level of "readiness" for reading instruction by administering one of the standardized reading readiness tests available (e.g., Metropolitan Readiness Test, Clymer Barrett Prereading Battery, Murphy-Durrell Readiness Test). Although results of such tests may be used to determine the method, materials and appropriate time to begin reading instruction, they are more often used to determine which children are most likely to fail in their initial encounter with formal reading instruction. Children who are identified as "at risk" may then be assigned to a readiness program that is designed to strengthen pre-reading skills. Such programs attempt to foster the development of skills considered prerequisite to reading instruction. For instance, children may be trained in visual discrimination, letter names, colors, shapes, rhyming, phonemic segmentation and motor tasks. The skills that are emphasized vary across readiness programs as do taxonomies of reading prerequisites and consequent early reading skills. Due to the diversity of those programs, it is inappropriate to generalize about the effectiveness of readiness programs.

Because different educators have believed that a variety of skills are related to subsequent reading achievement, reading readiness batteries have been designed to assess a wide range of abilities. Subtests include measures of visual discrimination, knowledge of letter names, sight word recognition, auditory discrimination, rhyming, following directions and vocabulary. Although these skills have been selected on the basis of observation of children during the period in which they acquire fundamental reading skills, they have not been selected to correspond to a model of reading acquisition. This is because a comprehensive model of reading acquisition does not yet exist. At this point, reading readiness is a psychometrically defined construct; that is, test development has preceded theoretical development. Several researchers have examined the relationship among pre-reading and subsequent reading achievement measures. As will be shown below in a review of such studies, there is no consensus as to the most important prerequisites or even the most meaningful predictors of reading achievement.

The second approach to compensatory education is designed to serve those considered "at risk" on the basis of their socio-economic status. The Head Start program was designed to provide the stimulation that children in lower socio-economic status (SES) homes may not receive. The goals of the program included social, emotional and cognitive growth and improvement of physical health and abilities. Evaluations of the national impact of Head Start have been controversial (e.g., Cicarelli, Cooper and Granger, 1969; Campbell and Erlebacher, 1970; Barnow, 1973; Datta, 1976; Magidson, 1977, 1978; Bentler and Woodward, 1978, 1979; Magidson and Sörbom, 1982). Those studies attempted to evaluate the impact of Head Start on a variety of subsequent performance measures.

This study attempted to amalgamate the two approaches by evaluating the impact of Head Start on reading acquisition. The objectives were twofold. First, a model of reading acquisition was to be developed. That model was to be tested on a longitudinal data set that consisted of cognitive and socio-economic measures that were administered over six years. Using structural equation modelling, a technique developed by Jöreskog and Sörbom (e.g., 1979), the analysis examined the causal relationship among latent SES, readiness and reading achievement variables. Second, the model was to be compared across treatment groups. The three groups were comprised of children who were enrolled in one of the following groups: Head Start, other preschool, no preschool. Initial and outcome differences among the groups and differential treatment effects were assessed in terms of means on the latent variables.

# CHAPTER 2

# LITERATURE REVIEW

Several bodies of literature will be examined. Initially a review of research on reading acquisition is presented. Then evaluations of Head Start are reviewed. Finally, the literature which supports the use of the proposed modelling procedures is subsumed in a separate chapter: General Procedure for Model Specification.

## Reading Acquisition

During the past century the emphasis of reading research has shifted from basic to applied and back to basic. The basic research began in the late 1800's when experimental psychologists began studying individual differences. Their work included research on psychological processes of reading (e.g., Cattell, 1886 and Quantz, 1897). However, two new areas of psychology altered the direction of reading research: the testing movement and behaviorism. First, Cattell's work on individual differences evolved from the study of psychological processes (Cattell, 1886) to the development of mental tests (Cattell, 1890). Then Watson's (1913) influence on experimental psychology curtailed the study of phenomena that were not directly observable and that included psychological processes of reading. Consequently, the study of reading was conducted by educators and educational psychologists and shifted from basic to applied research. Instructional methods and assessment became the two branches of reading research. In general, educators conducted unsystematic studies to determine the best method of reading instruction. The psychometricians' research, on the other hand, was based on statistical models, but not on psychological models of reading.

In the late 1950's, partly as a result of the Cooperative Research Act of 1954 (PL 83-531), basic research in reading began its resurgence (Venezky, 1977). The rather fruitless search for the best method led researchers to believe that an understanding of psychological processes of reading precluded determination of optimal instructional methods. Gibson and Levin's (1975) synthesis of the work of that period includes a thorough examination of both psychological and linguistic processes of reading. In the late 1970's and early 1980's the research perspective again began to shift. This time, unlike in the early 1900's, the change incorporated recent research findings. However, instead of examining separate or serial processes of reading as had been done to that point, interactive processes of reading became the focus. The Verbal Efficiency Theory (Perfetti, 1985) is the most comprehensive elaboration of that work.

The reading literature from the past century, as it pertains more specifically to reading acquisition, will now be reviewed. Although this will focus on reading acquisition, relevant research on the act of reading in general -- that which a young child attempts to master -- will be presented.

Venezky (1977) refers to the twenty year period that began around 1890 as "The Golden Years" (of basic research in reading). A great deal of the research conducted during that time remains pertinent today. For example, Javal (1879) determined that a reader's eye makes saccadic movements across the page. Erdmann and Dodge (1898) demonstrated that perception does not take place during saccades, only during fixation. Cattell (1886) determined that an individual can perceive a whole word more quickly than its individual letters. Quantz (1897) found that eye-voice span was greater in rapid readers and that reading speed was positively related to retention of text. Huey

(1908) examined and compiled the findings of that early work. Although his terminology differed, he basically presented an information-processing model of reading. It was a forerunner of models that are popular today.

Huey's (1908) book also included a large section on the pedagogy of reading and more specifically, a discussion of the optimal time to begin instruction. The problems of beginning reading instruction at age six were considered. He cited Dewey (1898) who stated that "...present physiological knowledge points to age about eight years as early enough for anything more than incidental attention to written and language-form"(p. 304). Huey went on to say that, "Reading must be postponed. The child is motor at this period when we teach him to read and must not do this passive thing so much"(p. 306). Then citing an article by Patrick (1899) entitled "Should Children Under Ten Learn to Read and Write?", Huey elaborated, "The nervous and muscular systems of the child indicate that he should not read and write so early. ... His brain is sensory and motor but not central. So he should learn to sense and perceive objects, real things, not deal mainly with symbols" (p. 308).

In the 1920's reading research generally focused on applied issues. For instance, reading readiness began receiving attention because retention of first graders was most often the result of a child's inability to read (Barrett, 1970). In fact, Deputy (1930) cited Percival (1926) who found that reading was responsible for over ninety-five percent of the first grade failures in a sample of thousands of California students. Even though Patrick (1898) used the term "mental readiness", the term "reading readiness" was first used by the National Commission on Reading in 1925 (Coltheart, 1979 and Anderson, Hiebert, Scott, and Wilkinson 1985). There were two contrasting perspectives on readiness at the time. Some educators believed that the unsuccessful students merely needed to mature, yet others felt that reading success would be more likely if prerequisite skills were taught.

Coltheart (1979) critically reviewed the early readiness research. Influential maturationists included Morphett and Washburne (1931) and Dolch and Bloomster (1937). Early proponents of component skills included Deputy (1930) and Gates (1937 and 1939). Morphett and Washburne claimed that the mental age of six and one-half was necessary for "satisfactory progress" in learning reading. Coltheart criticized two underlying assumptions of Morphett and Washburne. First, their definition of "satisfactory progress" was arbitrary. Second, the use of mental age as the sole criterion failed to account for differential learning rates of the bright young child and disabled older child each of whom may have a mental age of six and one-half. Despite these basic problems their work was very influential.

Dolch and Bloomster purported that the phonics approach to reading instruction could not be used successfully until the child reached a mental age of seven years. However, the phonics tasks used in their research were unnecessarily sophisticated for the generalizations made from their findings. Gates (1937) demonstrated that the relationship between mental age and reading achievement varied with instructional methods, materials, and personnel. Despite this, Coltheart presents literature citations as evidence of the unwarranted, yet long term, impact of Dolch and Bloomster's claim.

Component skills advocates believed that merely waiting for the child to mature was the wrong approach. They believed in the teaching of pre-reading skills to promote reading achievement. The National Commission on Reading (1925) encouraged the development of reading readiness programs for early first graders. The development of such a curriculum required identification of skills prerequisite to the mastery of fundamental reading. Deputy (1930) conducted one of the first comprehensive studies of the relationship among pre-reading and subsequent reading achievement tests. The pre-reading skills he measured included letter-word recognition, visual/auditory association, visual/visual association, listening comprehension, and mental age. His analyses based on these five variables resulted in a regression equation for predicting first grade reading achievement with a multiple correlation coefficient of 0.746.

In an experimental evaluation of readiness tests, Gates (1939) correlated reading achievement with eight pre-reading measures including: picture interpretation, rhyming, blending, word-card matching, word-matching, reading letters, sounding letters and mental age. Although total scores could be used to predict achievement, Gates believed that it was important for readiness subtest results to be used by teachers for guidance in providing students with work that appropriately matched their needs.

Component skills has generally replaced the maturation model. As a result reading readiness is no longer viewed as dichotomous, but as a continuous construct. Despite the general acceptance of a component skills model of reading readiness, there is little consensus as to which skills are the most related to subsequent achievement. The relationship of particular pre-reading skills and reading achievement varies across readiness batteries. For instance, correlations reported in the Eighth Mental Measurements Yearbook (Buros, 1978) range from 0.23 (Dykstra, 1978) to 0.66 (Ruth, 1978).

The applied research, which began in the 1920's, prevailed until the late 1950's when basic research resurfaced. At that point, investigators of reading acquisition were "...guided by theories which apply not only to reading but more generally to perceptual learning and to cognitive and linguistic development." (Gibson & Levin, 1975 p. 4). Gibson (1965) described three "roughly sequential" phases of learning tasks that a child goes through as he progresses from spoken to written language:

1) Differentiation of graphic symbols.
2) Decoding letters to sounds.
3) Using progressively higher-order units of structure.

Much of the research in the second era of basic research investigated the mastery of these tasks and progression through the phases. For example, Gibson, Osser, Schiff and Smith (1963) examined the probability that four year old children would confuse two letters. The number of errors for a pair of letters was positively related to the number of features that the pair shared. Then one must consider how a child differentiates between letters. Gibson (1965) explained that child must detect distinctive features of each grapheme. "A set of distinctive features for letters must be relational in the sense that each feature presents a contrast which is invariant under certain transformations, and it must yield a unique pattern for each letter" (Gibson, 1965, p. 1068).

Once a child can discriminate between letters, he can begin to learn to decode. Rozin and Gleitman (1977) state, "... the major problem in early reading acquisition is the complex and abstract relation between alphabetic writing and speech" (p. 133). Given our orthographic system, decoding is a skill which requires a child's understanding of grapheme-phoneme correspondences. How does a young child decode a word that is presented in our alphabet? Richardson, DiBennedetto, & Bradley (1977) suggest the following model of decoding a novel word:

1) Visual Analysis. The reader organizes the component letters spatially in a left-to-right order.

2) Sound-symbol correspondence. The reader orally produces the phonic sound corresponding to each of the component letters in a temporal order that matches the spatial order.
3) Blending. The reader orally produces an ordered blend of the sounds (p. 331).

Researchers have considered what skills are available for these processes and which the child must develop. In the first place when a child encounters formal reading instruction, he is already a competent speaker. Accordingly, oral language serves as the foundation for reading acquisition. The child's psycholinguistic competence includes auditory skills sufficient to distinguish between words, an implicit understanding of grammar and, of course, a vocabulary. However, some skills that are required for reading apparently have not yet been needed in speaking and listening. For instance, a young child need not analyze or synthesize word parts for effective oral communication. Consequently, kindergartners are inadequate at phonemic segmentation and blending tasks (Backman, 1983;Calfee, Chapman, & Venezky, 1972; Gibson & Levin, 1975; Liberman, Shankweiler, Liberman, Fowler, & Fischer, 1977).

Liberman, et al., (1977) demonstrated that children segment words into syllables more easily than into phonemes. However, it is the latter of these analytic skills which optimally uses our alphabetic orthography. Syllabication is undoubtedly a facilitative word identification skill, yet it is too advanced for a child's initial attempts to learn sound-symbol relationships. As the child matures, higher-order units are used. Gibson, Osser and Pick (1963) demonstrated that children in the latter part of first grade have already generalized some of the regularities of English orthography. A young reader progresses from a letter to letter-clusters and syllables. Eventually syntactic and then semantic cues are used to decode a word.

Gibson and Levin (1975) explained that reading involves more than the learning of distinctive features of graphemes and sound-symbol associations. They stated:

> To make use of the rule systems available in written text, the child must be able to perceive and make use of redundancy to reduce the information. ... economical processing of spelling patterns, abstraction of conditional rules in spelling, and use of syntax and hierarchical feature order to extract meaning are high-level perceptual and cognitive abilities needed for attainment of skilled reading (p. 254).

The study of reading processes has lasted nearly a century. Nevertheless, we do not yet know how reading is acquired nor when an individual child would benefit from formal reading instruction. Several tools of assessment are available. However, without a theoretical basis the results present an incomplete picture of the early reader. After reviewing research in the teaching and development of prereading skills, Gibson and Levin (1975) concluded:

> ... the answers to "reading readiness" are by no means all in. Mastery of the skills described above as components of reading does not necessarily insure instant success in learning to read, so far as we know at present. Teachers often ask whether, once a child has knowledge of components a and b and c and d, reading problems are effectively prevented. ... an intellectual task is not simply a sum of components -- especially reading, which is more than one task and differs with the material and the reader's purpose (p. 260).

The theoretical basis for a model of reading acquisition that has been missing may develop from some recent research on the skilled reader. Since the late 1970's, some researchers of reading processes have applied information-processing models that incorporate interactive processes (e.g., Lesgold and Perfetti, 1981; Ruddell and Speaker, 1985; and Rumelhart and McClelland, 1981). Unlike linear processes models (e.g., Gough, 1972 and

LaBerge and Samuels, 1974), these models allow information from higher-level processes (e.g., syntax or semantics) to affect lower-level processes (e.g., word identification). The Verbal Efficiency Theory (Perfetti, 1985) is the most comprehensive of these and for that reason will be discussed in some detail. Although Perfetti's is a model of skilled reading, and not one of early acquisition, it may help in the understanding of "what is acquired" in the process of reading acquisition.

The Verbal Efficiency Theory attempts to account for individual differences in reading comprehension, the outcome of the act of reading. It defines a skilled reader in terms of comprehension and reading rate relative to a given age group. The assumptions of the theory regard resources and attention that are available for mental processes. First, the resources are limited. "Working memory is the limited-capacity processing system that is constrained by the number of elements that can be simultaneously activated" (Perfetti, 1985, p. 100). Second, only attention-demanding processes are constrained by the limited resources. Third, individual control procedures allocate attention to the competing elements.

The central features of the theory have to do with efficiency of operation. Efficiency is defined in terms of outcome quality relative to processing costs. There are four overlapping processes: lexical access, propositional encoding, propositional integration and text modelling. Lexical access and propositional encoding are the two lower-level processes. If either demands disproportionate resources, reading performance could suffer. On the other hand, if both process with adequate efficiency, ample resources are more likely be allocated for the two higher-level processes: propositional integration and text modelling (i.e., interpretive, inferential and critical comprehension). These four processes comprise "text work". In a skilled reader, lexical access and propositional encoding require a small portion of resources relative to the two higher level processes. However, if a great deal of resources must be allocated for lexical access, less will be available for the remaining text work processes. As a consequence, comprehension will suffer. Because this is an interactive model, it is possible that weaknesses in one process can be compensated for by other processes. For example, a reader who is unable to decode an isolated word (e.g.. engine) can use the context (e.g., A red fire engine) for help.

How can this, a model of skilled reading, be applied to the study of reading acquisition? To incorporate it, a researcher must focus on the development of verbal efficiency. Since a reader's resources are limited, efficient lower-level processes allow more resources for comprehension. Consequently, development of rapid (and efficient) lexical access processes eliminate some-obstacles to skilled reading. Many aspects of lexical access in the beginning reader have already been investigated (e.g., component processes). However, facilitators of rapid lexical access, in the early reader, warrant further examination. In fact, it is unlikely that many studies which have attempted to predict reading achievement. using reading readiness batteries, have incorporated measures of speed. If a speed factor exists at all, on any of the popular readiness tests, it is that of time constraints, and not a measure of response time.

An additional application of Perfetti's theory in an investigation of reading acquisition is to incorporate the interactive nature of the reading processes. The use of non-recursive causal models may permit such an examination. In longitudinal research, one might attempt to incorporate the interaction of processes cross-sectionally. This could result in a more complete model of reading acquisition.

## Head Start

Head Start, one component of the government's war on poverty in the mid 1960's, was funded under Title II, the educational provision of the Economic Opportunity Act of 1964. In the summer of 1965 the first children were enrolled in Head Start programs. Those summer programs served over 500,000 children. In the fall of that year 20,000 enrolled in the full-year Head Start program. Within two years, over 200,000 were served in the full-year program (White, 1970).

The seven major objectives of Head Start (Cooke, 1965) are presented in Datta (1976):

1) Improving the child's physical health and abilities.
2) Fostering emotional and social development of the child by encouraging self-confidence, spontaneity, curiosity, and self-discipline.
3) Improving the child's mental processes and skills, with particular attention to conceptual and verbal skills.
4) Establishing patterns of expectations of success for the child that will create a climate of confidence for his future learning efforts.
5) Increasing s child's capacity to relate positively to family members and others while strengthening the family's ability to relate positively to the child and his problems.
6) Developing in the child and his family a responsible attitude toward society and fostering instructive opportunities for society to work together with the poor in solving their problems.
7) Increasing the sense of dignity and self-worth within the child and his family.

The first comprehensive evaluation of Head Start, conducted by Westinghouse Learning Corporation and Ohio University (Cicarelli, Cooper and Granger, 1969), was quite controversial. Using an ex post facto design, it was concluded that Head Start was generally ineffective. It found that children who participated in summer Head Start programs did not score higher than non-participants on cognitive or social measures. Furthermore, although the children in the full-year Head Start scored higher than the comparison group on the readiness tests in first grade, those differences did not exist on the second and third grade achievement tests. Recommendations of the report included phasing out the summer program, extending the period of intervention, "varying teaching strategies with the characteristics of the children", focussing on remediation of specific deficiencies and "training parents to become more effective teachers of their children" (Datta, 1976, p. 185).

That evaluation was criticized for methodological problems. Campbell and Erlebacher (1970) demonstrated that the "no effects" finding was likely to have been the result of regression artifacts. They showed that, in general, if the matched comparison group was more able than the treatment group at the outset (as is often the case in compensatory programs), Analysis of Covariance (ANCOVA) results understate positive effects and overstate negative effects of the treatment.

Barnow (1973) reanalyzed the Westinghouse/Ohio University data. He accounted for ethnicity, age and treatment in an ANCOVA with SES as the covariate. He concluded that the summer program was effective for Blacks and Mexican-Americans. However, the single, fallible indicator of SES violates the assumption of no measurement error in the covariate (Bentler & Woodward, 1979; Magidson, 1977). Magidson (1977) used a causal modelling approach to reanalyze a subset of the Barnow's data. Magidson incorporated four variables as measures of a "latent causative SES factor" and demonstrated small positive effects of Head Start. Bentler and Woodward (1978) praised Magidson's use of causal modelling and multiple indicators of SES, but criticized him for not comparing the fit of his "positive effects" models with the more parsimonious "no effects" models. That comparison was made by Bentler and Woodward (1978 & 1979) who concluded that Head Start had no effect in terms of the readiness outcome measures examined by Magidson. Bentler and Woodward (1978) further examined the data by using the two readiness tests as indicators of one latent outcome variable. That analysis again showed no Head Start effects on school readiness. Bentler and Woodward concluded that although their analyses are not the final word, the effectiveness of Head Start had not yet been demonstrated. Magidson (1978) replied to the criticisms of Bentler and Woodward (1978). He objected to the "... over-emphasis they place on the importance of the statistical test and especially their rigid adherence to the .05 significance level... " (p. 511). He stated that "educational significance" of the results is worthy of consideration and should not be disregarded solely on the basis of "statistical significance".

The Magidson (1977) and Bentler and Woodward (1978 and 1979) studies analyzed pooled covariance matrices that included a dummy coded (0,1) treatment variable. Bentler and Woodward suggested that the use of within-group covariance matrices would have allowed for a method more analogous to ANCOVA. Magidson and Sörbom (1982) incorporated the group means into an analysis of within-group covariance matrices. They compared the groups in terms of means on latent variables and concluded that their "... results do not support the strong negative inferences drawn of the original evaluators" (p. 328).

# CHAPTER 3

# GENERAL PROCEDURE FOR MODEL SPECIFICATION

Before elaborating on the methodology of the present study, an introduction to the statistical procedures will be presented. The procedures which form the basis for this study are path analysis, factor analysis and structural equation modelling. Path analysis is used to examine causal relationships among manifest variables. Factor analysis is used in attempting to explain the covariation among a set of observed variables in terms of unobserved factors. Causal relations among the latent variables can then be examined using structural equation modelling, a technique that employs both path and factor analytic methods. While this chapter discusses the general nature of these methods, the examples used to illustrate the methods are similar to the specific models tested in the study.

## Path Analysis

Path analysis, initially developed by Wright (1921 and 1934), is used to examine causal relationships among observed variables. Unlike multiple regression, which can include several independent variables but only one dependent variable, path analysis is a multivariate technique which can incorporate several independent and dependent variables. In this context, "exogenous" and "endogenous" are the terms used for explanatory and outcome variables. More specifically, an exogenous variable is one which is used solely as an explanatory construct in a system. A variable whose causes are other variables within the system is called endogenous.

As an example, consider a model with four standardized observed measures ($z_1$ through $z_4$). Suppose that two correlated exogenous variables, SES ($z_1$) and intelligence ($z_2$) are presumed to affect reading readiness ($z_3$), an endogenous variable. All three of these variables are hypothesized to affect reading achievement ($z_4$). This model is diagrammed in Figure 1. The causal paths from one variable to another are indicated by straight lines with an arrow at the affected variable. The correlations between exogenous variables (here SES and intelligence) are indicated by curved lines with a double-headed arrow, and $r_{ij}$ is the correlation of $z_i$ and $z_j$.

The relative strength of the causal relationships among individual variables is expressed in terms of path coefficients ($p_{ij}$). Comparable to standardized regression coefficients, they indicate the direct effect of one variable ($z_j$) on another ($z_i$). The part of $z_i$ that is not accounted for is represented by $e_i$.

The equations for the endogenous variables in this model (those variables for which we attempt to account for the variability) are:

$$z_3 = p_{31}z_1 + p_{32}z_2 + e_3$$

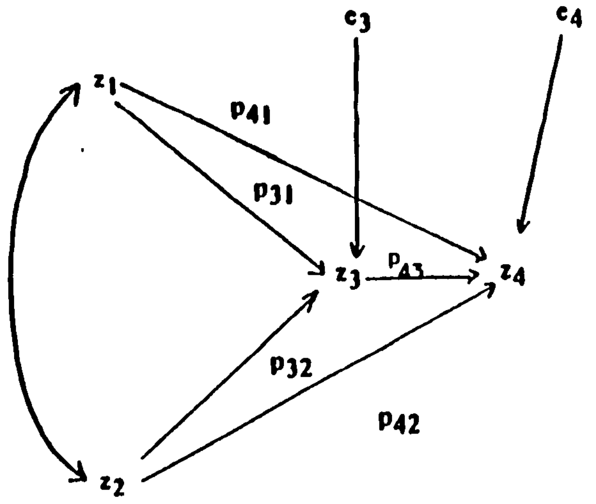
$$z_4 = p_{41}z_1 + p_{42}z_2 + p_{43}z_3 + e_4$$

Using standard techniques (e.g., Kenny, 1979) one can express the correlations among the $z_i$'s as functions of the $p_{ij}$ and $r_{ij}$ among the exogenous variables. If one can solve for all $p_{ij}$'s and variances of the $e_i$'s, then the model is said to be identified. The fit of the hypothesized model to the observed data can be examined using the chi-square goodness-of-fit test.

There are several assumptions of path analysis:

1) Linearity. There are linear relationships among the variables. Transformations may be necessary with non-linear data.
2) Additivity. There are no interactions.
3) Unbiased residuals. The residual of each variable is uncorrelated with any variable that precedes it in the model.
4) Complete model specification. All relevant variables are included in the model.
5) No measurement error. All variables are measured without error.

Violation of any of these assumptions may lead to biased parameter estimates.



$z_1$ SES

$z_2$ Intelligence

$z_3$ Reading Readiness

$z_4$ Reading Achievement

**Figure 1. Example of a Path Model**

## Factor Analysis: One Group

While path analysis is used to examine causal structures, factor analysis is used to determine the number of underlying variables measured by a set of observed variables. Many references distinguish between two broad approaches to factor analysis, principal components and common factor analysis (Kerlinger, 1973; Bentler, 1976; Jöreskog, 1979; Gorsuch, 1983). In principal components analysis, each component is a linear combinations of observed variables. With common factor analysis, each observed variable is a linear combination of the common and unique factors. (The distinction between common and unique factors is discussed below.) The following discussion concerns common factor analysis, a technique that extracts the underlying traits of the observed variables. Initially developed for the exploratory study of intelligence (Spearman, 1904; Thurstone, 1931), Jöreskog and Sörbom (e.g., 1978 and 1979) and others have developed methods of confirmatory factor analysis using maximum likelihood estimation.

As an example of the application of this technique, consider the following eight observed variables, labelled $x_1$ through $x_8$:

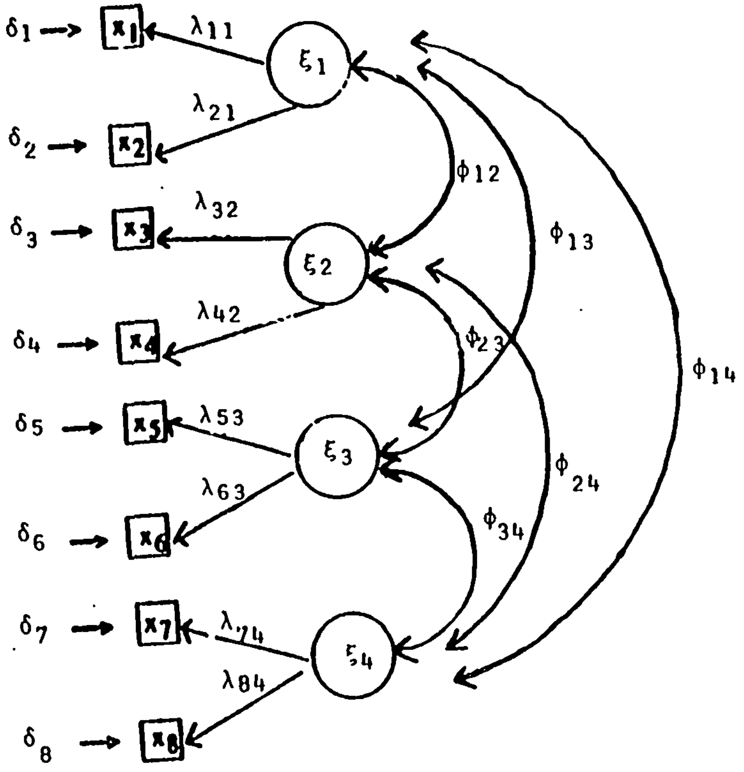
father's education ($x_1$)
mother's education ($x_2$)
intelligence test ($x_3$)
perceptual test ($x_4$)
rhyming ($x_5$)
picture matching ($x_6$)
word recognition ($x_7$)
paragraph comprehension ($x_8$)

An exploratory factor analysis can be used to examine the relationships (i.e., correlations or covariances) among the variables . Do the variables measure eight distinct constructs or are some variables measures of similar constructs? According to the factor analysis model, each observed variable can be expressed in terms of a linear combination of common factors ($\xi_j$) and unique factors ($\delta_i$). For example, in Figure 2, the eight observed variables above are shown as measures of four latent variables or factors.

In Figure 2 (and subsequent figures in this work) the observed variables are represented by rectangles and the latent variables by circles. The meaning of the notation used in the figures is as follows:

$\xi_j$ = common factor
$\lambda_{ij}$ = factor loading (the influence of factor j on variable i)
$\delta_i$ = unique factor or residual (that part of variable i not accounted for by the common factors).
$\phi_{ij}$ = covariance between $\xi_i$ and $\xi_j$.

A straight line from a factor with an arrow toward an observed variable represents the influence of that factor on the variable. The residual variables are represented by arrows coming from the periphery of the model to the respective observed variables. In the factor model, the variance in each observed variable can be accounted for by two kinds of sources: common and unique factors. Covariance among the observed variables is accounted for by the common factors (and correlations among those factors). The influence of Reading Readiness ($\xi_3$) on rhyming ($x_5$) is an example of this. Unique factors include two types of residual effects: that which is reliable and specific to the particular variable, and an unreliable part that is a result of measurement error.



| | |
|---|---|
| $x_1$ | Father's Education |
| $x_2$ | Mother's Education |
| $x_3$ | Intelligence |
| $x_4$ | Perception |
| $x_5$ | Rhyming |
| $x_6$ | Picture Matching |
| $x_7$ | Word Recognition |
| $x_8$ | Paragraph Comprehension |
| $\xi_1$ | SES |
| $\xi_2$ | Intelligence |
| $\xi_3$ | Reading Readiness |
| $\xi_4$ | Reading Achievement |

**Figure 2. Example of a Factor Model**

The equations which correspond to the above model are:

$$x_1 = \lambda_{11} \xi_1 + \delta_1$$

$$x_2 = \lambda_{21} \xi_1 + \delta_2$$

$$x_3 = \lambda_{32} \xi_2 + \delta_3$$

$$x_4 = \lambda_{42} \xi_2 + \delta_4$$

$$x_5 = \lambda_{53} \xi_3 + \delta_5$$

$$x_6 = \lambda_{63} \xi_3 + \delta_6$$

$$x_7 = \lambda_{74} \xi_4 + \delta_7$$

$$x_8 = \lambda_{84} \xi_4 + \delta_8$$

Or in matrix form:

$$\underset{\sim}{x} = \underset{\sim}{\Lambda} \; \underset{\sim}{\xi} + \underset{\sim}{\delta}$$

Standard assumptions about $\xi$ and $\delta$, and theory of variances and covariances of linear combinations, lead to the equation:

$$\Sigma = \Lambda\Phi\Lambda' + \psi$$

Where $\Sigma$ = the matrix of covariances among the observed variables

$\Lambda$ = the matrix of factor loadings whose general element is $\lambda_{ij}$

$\Phi$ = the matrix of covariances among the factors, $\phi_{ij}$

$\Psi$ = the matrix of covariances among the residuals, $\psi_{ij}$ (generally $\psi_{ij} = 0$, if $i \neq j$).

To determine the meaning of each latent trait, one must bear in mind the observed measures of each factor. For instance, in the above model, the factors might be labelled as follows:

$\xi_1$ = SES

$\xi_2$ = Intelligence

$\xi_3$ = Reading Readiness

$\xi_4$ = Reading Achievement

In this model, the relationship among the eight observed variables is explained by four hypothetical constructs: SES, Intelligence, Reading Readiness, and Reading Achievement.

Initially, exploratory factor analysis is often used to determine the number of factors and their relative effects on the given observed variables. It is unlikely that an exploratory factor analysis would result in a model in which each observed variable is clearly a measure of just one factor. Two steps could be taken which will result in a more interpretable model. First, rotation of the axes will result in a model with a simple structure. There are several methods of rotation (e.g., varimax, quartimax, and oblimin). Each type will result in a different factor solution. (For a comprehensive examination of rotation see, for example, Gorsuch, 1983.)

Second, a researcher could conduct subsequent confirmatory factor analyses in which low loadings (less than .30) are fixed equal to zero. Confirmatory factor models are used to test precise factor models generated by theory and/or exploratory factor analysis. The chi-square goodness-of-fit test is used to test the likelihood that the hypothesized model generated the observed data. A confirmatory factor analysis model which fits well can then be used as the basis of a structural equation model by specifying the factors as exogenous and endogenous. (This will be discussed below.)

Several assumptions must be met when using factor analysis. First, the expected value of each latent variable is equal to zero (i.e., $E(\xi_j)=0$). Second, the expected value of each residual is equal to zero (i.e., $E(\delta_i)=0$). Third, the common and unique factors are uncorrelated (i.e., $E(\xi_j \delta'_i)=0$). Additionally, one of the following constraints must be specified: either the common factor variances must be set equal to 1.0 (in order to do that, the diagonal elements of the factor variance-covariance matrix is fixed at one), or one loading for each factor must be constrained equal to 1.0.

### Factor Analysis: Several Groups

The procedures discussed to this point involve fitting models for one group of subjects. Factor models can also be compared across groups. LISREL VI (Jöreskog and Sörbom, 1981) is a computer program that can be used for simultaneous factor analyses in several populations. For instance, suppose a researcher wants to compare an experimental and a control group (random assignment is not necessary). Given two groups, each with exploratory models of good fit, one can test the fit of both models simultaneously. Using LISREL VI, various parameters of the factor models can be constrained across groups. Jöreskog and Sörbom (1979 and 1981) present examples of hypotheses regarding factor models that can be tested across groups. Several of those hypotheses will now be discussed.

Initially, one can test the hypothesis of equality of covariance matrices across groups ($H_1: \Sigma^{(1)} = \Sigma^{(2)}$ ,where the superscript designates group number). Using the factor model $\Sigma = \Lambda\Phi\Lambda' + \Theta_\delta$, the hypothesis is tested by specifying that the number of observed variables equals the number of factors and that:

$\Lambda = I$, the identity matrix

$\Theta_\delta = 0$ and

$\Phi^{(1)} = \Phi^{(2)}$, which imply that:

$\Sigma^{(1)} = \Phi^{(1)} = \Phi^{(2)} = \Sigma^{(2)}$.

If the resulting chi-square is not significant, the groups need not be analyzed separately and the pooled covariance matrix can be used for subsequent analyses. However, if the matrices are found to be significantly different, the factor models can be compared across groups. This can be done in a stepwise fashion in which models become progressively more parsimonious.

To illustrate this process, one can begin by testing the hypothesis that the models in each group have an equal number of factors ($H_2$). For example, given four observed measures for members of each group, does a two factor model fit the data from each group? The model is specified with the only restriction being that of an equal number of factors. The models for each group yield chi-squares which are independent of each other. Those chi-squares, therefore, are summed as are the corresponding degrees of freedom. The resulting chi-square indicates the likelihood that models from each group have the specified number of factors.

If that hypothesis is not rejected, one can then test the likelihood that the factor models in each group have the same factor pattern (i.e., have the same number of factors and the same observed measures of each factor). For example, given four observed measures for members of each group, would the following two factor model fit the data from each group:

| 1 | 2 |
|---|---|
| x | o |
| x | o |
| o | x |
| o | x |

where x = a factor loading to be estimated

o = a factor loading that is fixed at zero.

The chi-square of this model ($H_3$) is compared with that of $H_2$. If the difference in chi-squares of the two models is not significant for the corresponding difference in degrees of freedom, this hypothesis cannot be rejected.

A fourth, and more stringent, hypothesis can be tested by constraining the $\Lambda$ to be invariant across groups. By doing so, one tests the likelihood that all corresponding elements of the factor loading matrices are equal ($H_4$: $\Lambda^{(1)} = \Lambda^{(2)}$). The chi-square of this model is compared with that of $H_3$. Again, if the difference in chi-squares is not significant, this hypothesis cannot be rejected. Additionally, more restrictive models can be tested.

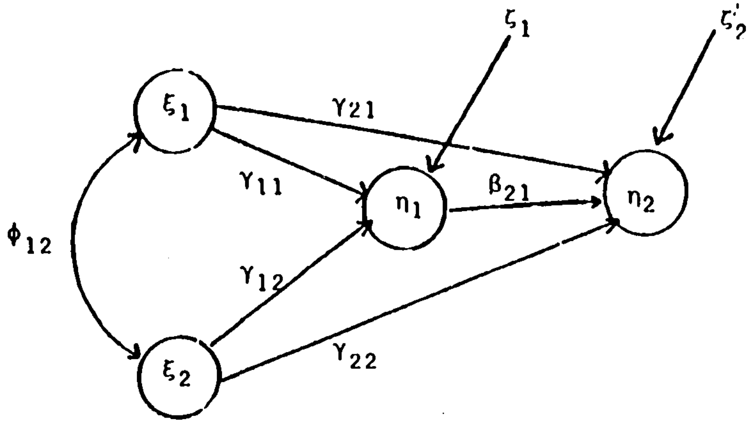
For instance, a fifth hypothesis is that in which we constrain both the $\Lambda$'s and $\Theta_\delta$'s equal across groups ($H_5$: $\Lambda^{(1)} = \Lambda^{(2)}$ and $\Theta_\delta^{(1)} = \Theta_\delta^{(2)}$). The resulting chi-square is, again, compared with that of the previous model ($H_4$, in this case).

By including the additional constraint of equal factor correlations, a sixth hypothesis, that of invariant factor models across groups, can be tested ($H_6$: $\Lambda^{(1)} = \Lambda^{(2)}$; $\Theta_\delta^{(1)} = \Theta_\delta^{(2)}$; $\Phi^{(1)} = \Phi^{(2)}$). That is, one can test a model in which the groups have identical factor loadings, residual variances and factor correlations. The chi-square of this model is compared with that of $H_5$.

## Structural Equation Modelling: One Group

As illustrated above, factor analysis is used to determine the number of latent variables measured by a group of observed variables, and path analysis is used to examine causal relationships among observed variables. A structural equation model combines the logic both of path and factor analyses. It is used to examine the causal relationships among latent variables. Structural equation models are composed of both structural and measurement models, the former being analogous to a path model and the latter analogous to a factor model. Thus, a researcher can attempt to account for the covariances among observed variables using a causal model of underlying constructs. This will be demonstrated by incorporating the path and factor models from the examples above. (Only a brief introduction to structural equation modelling will be presented here. More comprehensive discussions are presented in Jöreskog and Sörbom (1979), Rindskopf (1981), and Pedhazur (1982).)

A structural model is presented in Figure 3. The model includes two exogenous factors (SES, $\xi_1$, and Intelligence, $\xi_2$) and two endogenous factors (Reading Readiness, $\eta_1$, and Reading Achievement, $\eta_2$). The straight arrows from SES and Intelligence to Reading Readiness and Reading Achievement indicate the direct effect of each of those exogenous factors on each endogenous factor. The arrow from Reading Readiness to Reading Achievement indicates the direct effect of the former on the latter. (Note that the effects from exogenous to endogenous factors are each represented with a $\gamma_{ij}$, while the effects from endogenous to endogenous factors are each represented with a $\beta_{ij}$). The coefficient corresponding to each direct effect represents the strength of that effect. Additionally, each $\zeta_i$ indicates that portion of endogenous variable i not accounted for by the other latent variables. Moreover, the latent exogenous



| | |
|---|---|
| $\xi_1$ | SES |
| $\xi_2$ | Intelligence |
| $\eta_1$ | Reading Readiness |
| $\eta_2$ | Reading Achievement |

**Figure 3. Example of a Structural Model**

variables are specified as correlated; in general, $\phi_{ij}$ represents the covariance of exogenous variables *i* and *j*.

In addition to the structural model, a structural equation model includes a measurement component which relates the observed variables to the latentvariables. There is one measurement (or factor) model for the exogenous latent variables and one for the endogenous latent variables. Typical measurement models are illustrated in Figure 4. These models are similar to those presented in the above section on factor analysis (Figure 2) except that the exogenous and endogenous variables are considered separately. Note that the observed endogenous variables are represented with y's and the latent endogenous variables are represented with $\eta$'s, while observed exogenous variables are represented with x's and latent exogenous variables are represented with $\xi$'s. In general, the structural equation is:

$$\underset{\sim}{\eta} = \underset{\sim}{B}\,\underset{\sim}{\eta} + \underset{\sim}{\Gamma}\,\underset{\sim}{\xi} + \underset{\sim}{\zeta}$$

Where $\underset{\sim}{\eta}$ = a vector of latent endogenous variables, $\eta_i$.

$\underset{\sim}{B}$ = a matrix of coefficients, $\beta_{ij}$, which represent the direct effect of $\eta_j$ on $\eta_i$.

$\underset{\sim}{\Gamma}$ = a matrix of coefficients, $\gamma_{ij}$, which represent the direct effect of $\xi_j$ on $\eta_i$.

$\underset{\sim}{\xi}$ = a vector of latent exogenous variables, $\xi_j$.

$\underset{\sim}{\zeta}$ = a vector of variables, $\zeta_i$, which represent that portion of $\eta_i$ not accounted for by the model.

Specifically, the model illustrated above is, in matrix form:

$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0.0 & 0.0 \\ \beta_{21} & 0.0 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix}$$

| | |
|---|---|
| $x_1$ | Father's Education |
| $x_2$ | Mother's Education |
| $x_3$ | Intelligence |
| $x_4$ | Perception |
| $\xi_1$ | SES |
| $\xi_2$ | Intelligence |

| | |
|---|---|
| $y_1$ | Rhyming |
| $y_2$ | Picture Matching |
| $y_3$ | Word Recognition |
| $y_4$ | Paragraph Comprehension |
| $\eta_1$ | Reading Readiness |
| $\eta_2$ | Reading Achievement |

Figure 4. Examples of the Measurement Models

The equations for the measurement model are:

$$\underset{\sim}{x} = \underset{\sim}{\Lambda}_x \underset{\sim}{\xi} + \underset{\sim}{\delta}$$

$$\underset{\sim}{y} = \underset{\sim}{\Lambda}_y \underset{\sim}{\eta} + \underset{\sim}{\varepsilon}$$

Where

$\underset{\sim}{x}$ = a vector of observed exogenous variables

$\underset{\sim}{\Lambda}_x$ = a matrix of factor loadings

$\underset{\sim}{\xi}$ = a vector of latent exogenous variables

$\underset{\sim}{\delta}$ = a vector of residuals,

$\underset{\sim}{y}$ = a vector of observed endogenous variables

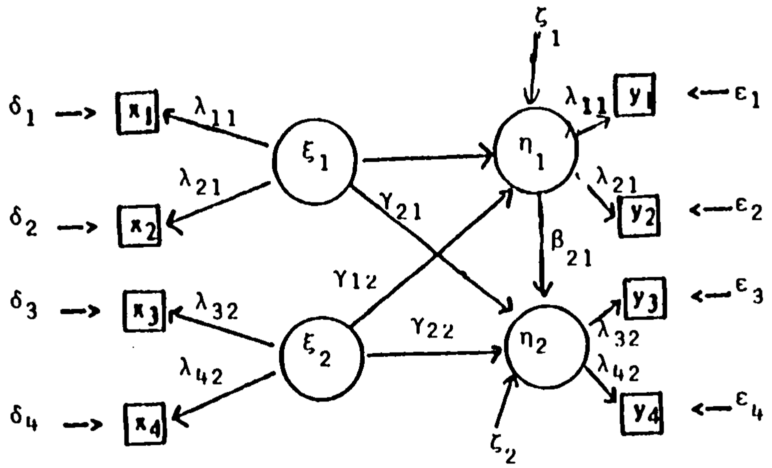
$\underset{\sim}{\Lambda}_y$ = a matrix of factor loadings

$\underset{\sim}{\eta}$ = a vector of latent endogenous variables

$\underset{\sim}{\varepsilon}$ = a vector of residuals.

Finally, combining the structural and measurement models we get a structural equation model. This model is presented in Figure 5.

There are several assumptions in a structural equation model. First, the expected value of each latent exogenous and endogenous variable is zero (i.e., $E(\eta_i)=E(\xi_j)=0$). Furthermore, the expected value of each residual in both the structural and measurement models equals zero (i.e., $E(\delta_j)=E(\varepsilon_i)=E(\zeta_i)=0$). Additional assumptions regard uncorrelated components of the model. The errors of measurement are uncorrelated with the latent variables (i.e., $E(\xi\delta') = E(\eta\varepsilon') = E(\eta\zeta') = \underset{\sim}{0}$). The error terms are mutually uncorrelated (i.e., $E(\delta\zeta') = E(\delta\varepsilon') = E(\varepsilon\zeta') = 0$), but they may be correlated among themselves. This restriction is not strictly necessary, and may be relaxed for some models.



| | |
|---|---|
| $x_1$ | Father's Education |
| $x_2$ | Mother's Education |
| $x_3$ | Intelligence |
| $x_4$ | Perception |
| $\xi_1$ | SES |
| $\xi_2$ | Intelligence |

| | |
|---|---|
| $y_1$ | Rhyming |
| $y_2$ | Picture Matching |
| $y_3$ | Word Recognition |
| $y_4$ | Paragraph Comprehension |
| $\eta_1$ | Reading Readiness |
| $\eta_2$ | Reading Achievement |

Figure 5. Example of a Structural Equation Model

## Structural Equation Models: Several Groups

As with factor models, one can compare groups using structural equation models. A practical approach to such a comparison involves fitting a series of models beginning with separate structural equation models for each group. Then, given two groups, for example, each with models of reasonable fit and comparable structures, one can analyze data from both groups simultaneously. The fit of this model, the first simultaneous group model, that with no parameters constrained equal across the groups, is used for comparison with the subsequent models. One can test any of the six hypotheses presented above in the above section "Factor Analysis: Several Groups". Assumptions that must be met in this model are basically the same as those presented for the general structural equation model. Instead of elaborating on this method of comparing groups, a more comprehensive model, LISREL with structured means, is now introduced.

## Structural Equation Models: Structured Means

Given more than one group, a model can be specified that incorporates the group means for each observed variable, in addition to the group covariances. By doing so, the model can attempt to account for initial and outcome differences and differential treatment effects in terms of latent constructs. This technique will be demonstrated with an example that includes four of the observed variables from the above models: rhyming ($y_1$), picture matching ($y_2$), word recognition ($y_3$) and paragraph comprehension ($y_4$). The former two variables are specified as observed measures of the latent construct, Reading Readiness ($\eta_1$), and the latter two are observed measures of Reading

Achievement ($\eta_2$). Assume that a treatment group (group 1), attended kindergarten, whereas the comparison group (group 2), did not.

In addition to those two latent variables, this model includes $\xi_1$ and $\eta_3$ which are defined as equal to 1.0 for reasons discussed below. The structural and measurement models are presented in Figures 6 and 7, respectively. The latent variables $\xi_1$ and $\eta_3$ are not really random variables, but actually constants, equal to 1.0. They are included as intercepts in the structural and measurement models, respectively. In this procedure the sample matrices of moments about zero are analyzed. (In the structural equation models presented above, the sample covariance matrices were analyzed.)

The equations for the structural model:

$$\eta_1 = \gamma_{11}^{(g)} \xi_1 + \zeta_1$$

$$\eta_2 = \gamma_{21}^{(g)} \xi_1 + \beta_{21}^{(g)} \eta_1 + \zeta_2$$

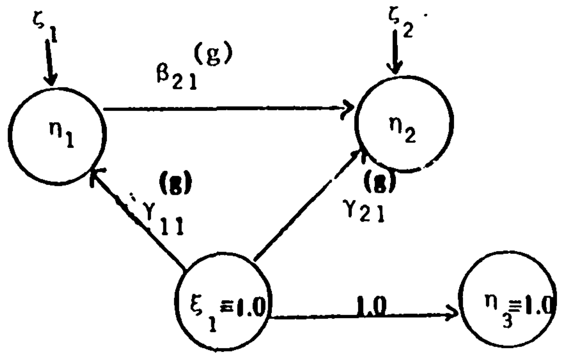
Because $\xi_1 = 1.0$, these simplify to :

$$\eta_1 = \gamma_{11}^{(g)} + \zeta_1$$

$$\eta_2 = \gamma_{21}^{(g)} + \beta_{21}^{(g)} ( \gamma_{11}^{(g)} + \zeta_1) + \zeta_2$$

In matrix form:

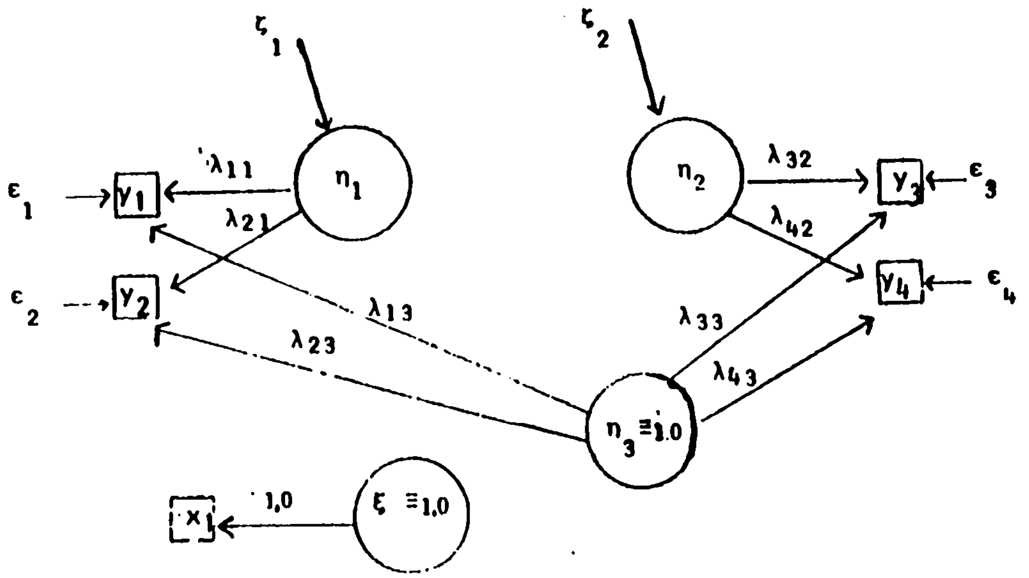
$$\begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} = \begin{bmatrix} 0.0 & 0.0 \\ \beta_{21} & 0.0 \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \end{bmatrix} + \begin{bmatrix} \gamma_{11} \\ \gamma_{21} \end{bmatrix} \begin{bmatrix} \xi_1 \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_2 \end{bmatrix}$$



$\eta_1$ Reading Readiness

$\eta_2$ Reading Achievement

**Figure 6. Example of Structured Means: Structural Model**



| | |
|---|---|
| $\eta_1$ | **Reading Readiness** |
| $\eta_2$ | **Reading Achievement** |
| $y_1$ | **Rhyming** |
| $y_2$ | **Picture Matching** |
| $y_3$ | **Word Recognition** |
| $y_4$ | **Paragraph Comprehension** |

Figure 7. Example of Structured Means: Measurement Model

The equations for the measurement model are:

$$y_1 = (1)\ \eta_1 + \lambda_{13}^{(g)}\ \eta_3 + \varepsilon_1$$

$$y_2 = \lambda_{21}^{(g)}\ \eta_1 + \lambda_{23}^{(g)}\ \eta_3 + \varepsilon_2$$

$$y_3 = (1)\ \eta_2 + \lambda_{33}^{(g)}\ \eta_3 + \varepsilon_3$$

$$y_4 = \lambda_{42}^{(g)}\ \eta_2 + \lambda_{43}^{(g)}\ \eta_3 + \varepsilon_4$$

$\eta_3 \equiv 1.0$, so:

$$y1 = \eta_1 + \lambda_{13}(g) + \varepsilon_1$$

$$y2 = \lambda_{21}(g)\eta_1 + \lambda_{23}(g) + \varepsilon_2$$

$$y3 = \eta_2 + \lambda_{33}(g) + \varepsilon_3$$

$$y4 = \lambda_{42}(g)\ \eta_2 + \lambda_{43}(g) + \varepsilon_4$$

In matrix form, these equations are:

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ y_4 \end{bmatrix} = \begin{bmatrix} 1.0 & 0.0 & \lambda_{13}^{(g)} \\ \lambda_{21}^{(g)} & 0.0 & \lambda_{23}^{(g)} \\ 0.0 & 1.0 & \lambda_{33}^{(g)} \\ 0.0 & \lambda_{42}^{(g)} & \lambda_{43}^{(g)} \end{bmatrix} \begin{bmatrix} \eta_1 \\ \eta_2 \\ \eta_3 \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \varepsilon_3 \\ \varepsilon_4 \end{bmatrix}$$

Many of the assumptions of this model are the same as those of the general structural equation model. For instance, errors of measurement are uncorrelated with the latent variables (i.e., $E(\xi\delta') = E(\eta\varepsilon') = E(\delta\zeta') = 0$). Also, it is still assumed that the expected value of each residual equals zero (i.e., $E(\delta_i) = E(\varepsilon_j) = E(\zeta_i) = 0$). However, assumptions having to do with the expected values of the latent variables are modified. Specifically, $E(\eta_1)$ and $E(\eta_2)$ are no longer constrained to equal zero. Furthermore, as mentioned above, $\xi_1$ and $\eta_3$ are actually constants, $E(\xi_1) = E(\eta_3) = 1.0$.

For purposes of identification the factor loadings are usually constrained equal across groups (i.e., $\Lambda_y^{(1)} = \Lambda_y^{(2)}$ )although less stringent constraints are sometimes possible. In order to identify the group means in terms of latent variables, one must set $\gamma_{11}^{(1)} = \gamma_{21}^{(1)} = 0$ for one group, the comparison group in this case. Accordingly, the structural model (in terms of expected values), for the comparison group, simplifies to:

$$E(\eta_1)^{(1)} = 0.$$

$$E(\eta_2)^{(1)} = 0.$$

Because $\xi_1 = 1.0$, the expected values for the treatment group simplify to:

$$E(\eta_1)^{(2)} = \gamma_{11}^{(2)}.$$

$$E(\eta_2)^{(2)} = \beta_{21}^{(2)}\gamma_{11}^{(2)} + \gamma_{21}^{(2)}.$$

As a consequence of setting $\gamma_{11}^{(1)} = \gamma_{21}^{(1)}=0$ and constraining $\eta_3=1.0$, $E(\eta_1)^{(1)} = E(\eta_2)^{(1)} = 0$. Therefore, the measurement model for group one (in terms of expected values) simplifies to :

$$E(y_1)^{(1)} = \lambda_{13}.$$

$$E(y_2)^{(1)} = \lambda_{23}.$$

$$E(y_3)^{(1)} = \lambda_{33}.$$

$$E(y_4)^{(1)} = \lambda_{43}.$$

That is, the factor loadings for $\eta_3$ represent the means of the respective observed variables for group one.

To determine group differences in the structural model, one subtracts expected values of the corresponding pairs of latent background and outcome variables. This will be demonstrated with a series of three hypotheses: no initial differences, parallel slopes and no treatment effects.

The hypothesis of no initial differences amounts to examining the differences between groups in terms of $E(\eta_1)^{(g)}$ (i.e., $E(\eta_1)^{(2)} - E(\eta_1)^{(1)}$ ):

$$H_1: \gamma_{11}^{(1)} = \gamma_{11}^{(2)}$$

Since $\gamma_{11}^{(1)} = 0$, this is equivalent to testing $H_1': \gamma_{11}^{(2)} = 0$.

The chi-square of this model is compared with that of the model in which $\gamma_{11}^{(2)}$ was not constrained to equal zero. If there is not a significant difference in fits, one can conclude that there is no initial difference across groups.

Similar to the logic of ANCOVA, before treatment effects can be examined, one should test for parallel slopes of the regression of $\eta_2$ on $\eta_1$ . This involves testing for equality of $\beta_{21}^{(g)}$ across groups:

$H_2$: $\beta_{21}^{(1)}=\beta_{21}^{(2)}$

If $H_2$ is rejected, an interaction between treatment and $\eta_1$ exists. In such a case, the treatment effect is examined by considering the conditional expectation $E(\eta_2| \eta_1) = \gamma_{21}^{(g)} + \beta_{21}^{(g)} \eta_1$ . That is, conclusions regarding the treatment effect must specify the level of $\eta_1$.

However, if the slopes are parallel one need not consider the level of $\eta_1$ in order to examine treatment effects. In such a case the unconditional expectation is considered: $E(\eta_2)= \gamma_{21}^{(g)} + \beta_{21}^{(g)} E(\eta_1^{(g)})$. The differences between groups in terms of the latent outcome variable:

$$E(\eta_2| \eta_1)^{(2)} - E(\eta_2| \eta_1)^{(1)} = (\gamma_{21}^{(2)} + \beta_{21}^{(2)}\eta_1 - (\beta_{21}^{(1)}\eta_1)$$
$$= \gamma_{21}^{(2)} - \eta_1( \beta_{21}^{(2)} - \beta_{21}^{(1)} ).$$

When the slopes are parallel, the difference simplifies to:

$$E(\eta_2| \eta_1)^{(2)} - E(\eta_2| \eta_1)^{(1)} = \gamma_{21}^{(2)}.$$

In this case, the no treatment effect hypothesis is: $H_3$: $\gamma_{21}^{(1)} = \gamma_{21}^{(2)}$.

Or, since $\gamma_{21}^{(1)} = 0$, $H_3'$: $\gamma_{21}^{(2)} = 0$.

In summary, one cannot find absolute origins for the latent constructs $\eta_1$ and $\eta_2$. However, by arbitrarily setting the expected values of those constructs equal to zero for one of those groups and by constraining $\xi_1 = \eta_3 = 1.0$, adjustments for initial differences can be made and treatment effects determined.

This has distinct advantages over analysis of covariance (ANCOVA), a more popular, but frequently misused (as discussed in Sörbom, 1978), method of adjusting for group differences. First, by comparing groups in terms of latent constructs, measurement error is not a problem. Second, this method can account for the interaction of treatment with initial status, which can be, but is not usually, incorporated into the ANCOVA model.

# CHAPTER 4

# METHODOLOGY

## The Data Set[1]

The Longitudinal Study of Disadvantaged Children and their First School Experiences, a joint project of Educational Testing Service and the Head Start Research Office of the Office of Economic Opportunity, began in 1967. The questions which the study was designed to address included (Shipman, 1970, p. 1):

1) What are the components of early education that are associated with cognitive, personal and social development of disadvantaged children?
2) What are the environmental and background variables that moderate these associations?
3) How do these moderators produce their influence?

However, the study explicitly states that it is not intended to be an evaluation of the Head Start program, "... at least in the narrow sense of implying 'go/no go' recommendation".[2]

## The Sample

Four "regionally distinct communities" were selected using the following criteria (Shipman, 1972, p. 3):

1) Those which "had sufficient number of children in school and in the Head Start program"
2) Those which "appeared feasible for longitudinal study given expressed community and school cooperation and expected mobility rates"
3) Those which "offered variation in preschool and primary grades experiences".

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[1] This material comes from ETS Documents PR-70-20 and PR-72-27.

[2] It is further stated that because of the heterogeneity of Head Start programs, evaluation of these sites is not an evaluation of Head Start nationwide.

The sites selected include Lee County, Alabama; Portland, Oregon; St. Louis, Missouri; and Trenton, New Jersey.

> Within these communities, elementary school districts with substantial proportion of the population eligible for Head Start were selected for participation. For the most part, schools in target districts are located near Head Start centers. It is in these school districts that the sample was expected to be enrolled by third grade, in the fall of 1973. In each school district an attempt was made to include all children of approximately three and one-half to four years and one-half years of age in the initial testing and data collection of 1969. However, some of the children were specifically excluded from the sample (e.g., children from families whose primary language was not English and those with severe handicaps). (Shipman, 1972, p. 4)

The school years and corresponding years of the ETS Longitudinal Study are presented along with grades in school and ages in Table 1. All children who were in Head Start attended in Year Two (1969-1970) of the study, except those in Lee County, where they attended Head Start as a kindergarten-level program in Year Three. The sample size varies at each site. In the sample of 1875 children (on whom at least partial data were obtained) 53% are male. Of those children in the three sites which offered Head Start in Year Two of the study, 37.2% attended Head Start, 11% attended another preschool and 51.8% "had no known attendance in Head Start or other preschool programs". The kindergarten-level Head Start program of Lee County included 41.1% of the children at that site, whereas 19.1% attended other preschool and 39.3% had no known attendance in any preschool programs. The enrollment in Head Start was racially disproportionate: only 5.1% of the Head Start children are white, even though approximately 38% of the sample is white.

Data Collection Procedures

ETS enlisted community participation in the data collection procedure. By so doing, the consequent community support and involvement was expected to facilitate the collection of meaningful data. Local staff were carefully selected

Table 1

Chronology of the EIS-Head Start Longitudinal Study

| School Year | Year of Study | Grade | Age Range |
|---|---|---|---|
| 1968-1969 | One | —— | 3.5 to 4.5 |
| 1969-1970 | Two | Preschool | 4.5 to 5.5 |
| 1970-1971 | Three | Kindergarten | 5.5 to 6.5 |
| 1971-1972 | Four | One | 6.5 to 7.5 |
| 1972-1973 | Five | Two | 7.5 to 8.5 |
| 1973-1974 | Six | Three | 8.5 to 9.5 |

and trained to serve as coordinators, interviewers and testers in each of the four geographic regions. Identification of eligible children in each locality was conducted by Audits and Surveys of New York. In order to obtain background information on these children, their caretakers were interviewed by the staff of Audits and Surveys.

After the local staff completed extensive training in the use of a battery of instruments adapted for the settings and purposes of the study, arrangements were made to begin testing. Testing was to take place in community facilities. Scheduling was flexible and transportation was provided in order to encourage maximum participation. On each of four days, children were individually tested for approximately 90 minutes. Because of the age of those being tested, examiners were told to wait until the subjects were ready and allow for breaks from testing as necessary. The procedures were similar in Year Two except that, because of a reduction in the number of instruments administered, only three days of testing were required for each child. In Years Three through Six the data collection generally shifted from individual to group settings. In classes in which at least fifty percent of the students had been previously tested for the longitudinal study, classroom teachers administered achievement tests (Shipman, 1976; Shipman, McKee, & Bridgeman, 1976).

## Original Analysis Plan

The analyses that were originally planned are presented in this chapter. As will be detailed in the next chapter, not all analyses that were planned were conducted. Moreover, several analyses that were not originally anticipated were performed.

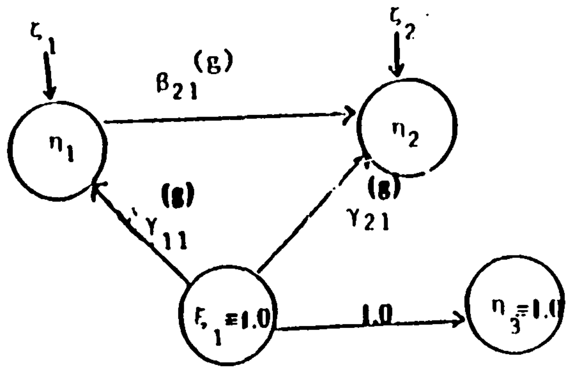
The proposed analyses included six stages: three using confirmatory factor analyses and three using structural equation models. Although a researcher might want to begin by testing the hypothesized 'final model', it is virtually impossible because the model-building process may result in one of variety of models, depending on the nature of the data. Instead, one must start with the least restrictive model and incorporate the results of each successive stage as the model becomes more refined. The resulting model, therefore, incorporates both theoretical and empirical demands.

Initially, the three treatment groups were to be considered independently. Confirmatory factor analyses were to be conducted on five covariance matrices per group, each of which was to include observed variables from one of the following groups: year one, year two, year three, years four, five, and six, and parent interview. The second stage was to have examined the groups simultaneously. Confirmatory factor analyses, initially with no constraints across the three groups, were to be conducted. At stage three, the analyses were to incorporate constraints across groups into the model. Specifically, the likelihood of similar factor structures across groups was to be tested, as discussed in a previous section, "Factor Analysis: Several Groups".

The longitudinal nature of the data was then to be considered. Initially, separate structural equation models were to be tested for each of the three treatment groups. The exact components of these models of reading acquisition were to depend upon the outcome of the confirmatory factor analyses. However, it was anticipated that the models developed in this, the fourth stage, would include latent constructs such as SES, pre-treatment readiness, post-treatment readiness and post first grade reading instruction reading achievement. After models had been fit for each group, simultaneous structural equation models were to be analyzed in stage five. The initial analyses were not to involve constraints across groups, but instead were to test the likelihood of the simultaneous fit of the three group models.

Subsequent analyses were to incorporate group means in addition to the covariance matrices. Consequently, structured means could be examined in stage six. Specifically, initial differences (e.g., SES and Readiness) were to be incorporated into the model of reading acquisition. Group differences on those outcome constructs (e.g., Reading Achievement) found in prior analyses could also be accounted for in the model.

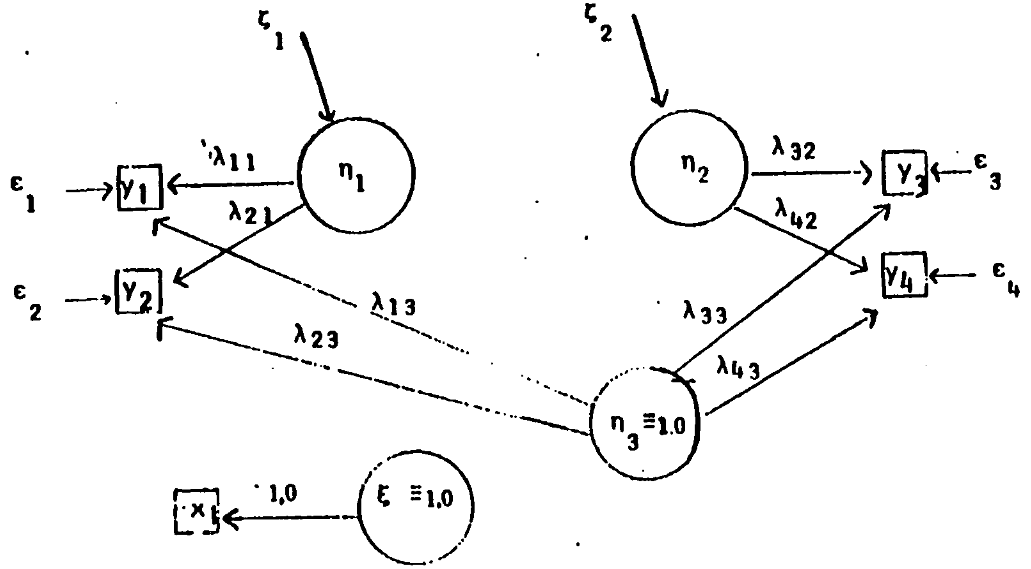
In order to demonstrate this proposed approach, a hypothetical model with only two latent constructs, Readiness ($\eta_1$) and Reading Achievement ($\eta_2$), is presented in Figures 8 and 9. The model includes two observed measures of each latent construct. In addition, $\xi_1$ and $\eta_3$ are included and defined equal to 1.0. The former is included to account for group differences in the structural model. On the other hand, $\eta_3$ is included to account for group differences in the measurement model.



$\eta_1$ Reading Readiness

$\eta_2$ Reading Achievement

Figure 8. Structured Means: Proposed Structural Model



| | |
|---|---|
| $\eta_1$ | **Reading Readiness** |
| $\eta_2$ | **Reading Achievement** |
| $y_1$ | **Rhyming** |
| $y_2$ | **Picture Matching** |
| $y_3$ | **Word Recognition** |
| $y_4$ | **Paragraph Comprehension** |

Figure 9. Structured Means: Proposed Measurement Model

The equations for the structural model:

$$\eta_1 = \gamma_{11}^{(g)} + \zeta_1$$

$$\eta_2 = \gamma_{21}^{(g)} + \beta_{21}^{(g)} \eta_1 + \zeta_2$$

The equations for the measurement model:

$$y_1 = (1)\,\eta_1 + \lambda_{13}\,\eta_3 + \varepsilon_1$$

$$y_2 = \lambda_{21}\,\eta_1 + \lambda_{23}\,\eta_3 + \varepsilon_2$$

$$y_3 = (1)\,\eta_2 + \lambda_{33}\,\eta_3 + \varepsilon_3$$

$$y_4 = \lambda_{42}\,\eta_2 + \lambda_{43}\,\eta_3 + \varepsilon_4$$

Three within-group moment matrices were to be analyzed. The model was to be specified such that $\gamma_{11}^{(1)} = \gamma_{21}^{(1)} = 0$, where group one is the "no treatment" group. By making such a specification, $E(\eta_1)^{(1)} = E(\eta_2)^{(1)} = 0$. Groups two and three are Head Start and "other preschool", respectively. The series of three hypotheses which were presented above (see "Structural Equation Models: Structured Means") was to be followed.

Specifically, initial differences in Readiness were to be examined first. The hypotheses:

$H_{1a}$: $\gamma_{11}^{(2)} = 0$ (no Readiness differences between no treatment and Head Start)

$H_{1b}$: $\gamma_{11}^{(3)} = 0$ (no Readiness differences between no treatment and other preschool)

The second hypotheses, those of parallel slopes of the regression of $\eta_2$ on $\eta_1$, were then to be tested:

$H_{2a}$: $\beta_{21}^{(1)} = \beta_{21}^{(2)}$ (Slopes for no treatment and Head Start are parallel.)

$H_{2b}$: $\beta_{21}^{(1)} = \beta_{21}^{(3)}$ (Slopes for no treatment and other preschool are parallel.)

If this second hypothesis was not rejected, outcome differences among groups were to be examined in terms of the latent construct, Reading Achievement. As demonstrated above this simplifies to:

$H_{3a}$: $\gamma_{21}^{(2)} = 0$ (no Reading Achievement difference between no treatment and Head Start)

$H_{3b}$: $\gamma_{21}^{(3)} = 0$ (no Reading Achievement difference between no treatment and other preschool)

However, if the second hypothesis was rejected, outcome differences were to be examined in terms of the conditional expectation $E(\eta_2|\eta_1)$ . That is, because non-parallel slopes would indicate an interaction of Readiness ($\eta_1$) and treatment, the treatment effects would have been examined separately for specific levels of $\eta_1$. It was anticipated that this approach would help clarify which treatment was most beneficial for different levels of readiness.

These proposed analyses provided a guiding strategy for analyzing the data. However, as will be shown in the next chapter, because of missing data, the actual analyses differed from those that were originally proposed when the longitudinal nature of the data was considered.

# CHAPTER 5

# RESULTS

Initially, measures of interest for the development of a model of reading acquisition were identified from variables in the Educational Testing Service (ETS) Longitudinal Study data base. The names of these instruments are presented in Appendix A. ETS provided the data for the measures of interest on seven magnetic computer tapes. Data for each measure were in separate files on the tapes. The data generally came in the form of item responses on each measure. It included measures from each of the first six years of the study and a subset of items from a parent interview conducted in year one.

Documentation that accompanied the file layouts included criteria for scoring each instrument. In order to compute each score, a minimum number of responses was required. (The minimum varied across instruments.) If the minimum criteria was met, all item responses were examined; values that did not fall within valid ranges were treated as missing data. Total and subtest scores were computed for each instrument. In general, total scores were defined as the number of correct responses. Consequently, no response to an item was scored the same as an incorrect response. As with individual items, scores which were beyond acceptable ranges were treated as missing. These scores were merged into one large data base by matching subjects using the ETS identification numbers.

The selection of subjects and variables for the preliminary analyses was based on several criteria. Initially, subjects were eliminated from the data set if they did not have measures of constructs such as reading readiness and achievement (e.g., Metropolitan Readiness Test and Cooperative Primary Tests).

Next, variables were eliminated. Reduction of variables began with the examination of sample sizes for each instrument. Those tests that were given to a small subset of the subjects were eliminated from consideration because they would limit the longitudinal sample size of the present study. The data for the remaining subjects were then factor analyzed. Initially, exploratory factor analyses were conducted on variables within a particular year. In addition to the six years of data, the parent interview data comprised a seventh set of variables that were factor analyzed. The exploratory factor analyses were used to examine the relationships among the manifest variables in terms of latent variables.

Confirmatory factor analyses were then used to test hypotheses about the variables that seemed to fit well together in the exploratory analyses. These variables are described in Appendix B. The variables were grouped somewhat differently at this stage. Although cross-sectional models were tested for each of the first three years and the parent interview variables, the reading achievement variables, those from years four, five, and six were considered together. Appendix C presents the best fitting confirmatory factor analysis models. These models will be discussed in the following sections. The St. Louis subjects were excluded from the study at this point in the analyses, because only a limited number of measures were administered at that site. About thirty observed measures remained in the data base after eliminating those instruments that were not administered to many subjects and those that did not fit well in the factor models.

For all analyses, chi-square was used as the criterion of goodness-of-fit. A chi-square goodness-of-fit test examines the similarity of the estimated and observed covariance matrices. A small chi-square relative to the number of degrees of freedom indicates that it is tenable that the hypothesized model generated the observed data. A potential problem with this assessment of goodness-of-fit is that it is approximately proportional to the sample size. As a result, it is not powerful with a small sample. Furthermore, models tested on very large samples are unlikely to fit. Another potential problem with this test is its sensitivity to highly skewed distributions (Saris and Stronkhorst, 1984). In this study, we had reasonable sample sizes and the variables were not strongly skewed. Consequently, we used chi-square to assess the fit of the models.

An informal method of evaluating the fit of a model is to examine the residuals (i.e., the differences between the corresponding elements of the estimated and observed covariance or correlation matrices). Residuals do not vary with sample size; however, there are no firm rules on what size residual is reasonable. Their interpretation is more difficult when analyzing covariances than with correlations.

Differences in chi-squares of nested models can be used to test the significance of a parameter or set of parameters included in the less restricted model. Several examples of this are presented in Chapter Three. Bentler and Bonett (1980) developed an incremental fit index. Using that index, which is not sensitive to sample size, one can test the necessity of the parameters that are included in the hypothesized model. For example, suppose $X^2_A$ is the likelihood ratio goodness-of-fit statistic for the model being tested and $X^2_B$ is for the null model. The equation for the incremental fit index is $I_{AB} = (X^2_B - X^2_A)/X^2_B$. This was meant to be analogous to the proportion of variance accounted for in multiple regression. Bentler and Bonett have guidelines for interpretation of the index. They propose using 0.90 as an acceptable value. However, this guideline has no statistical basis.

Cross-sectional Models: Pooled Models

The Parent Interview model consists of five parent interview questions, which were hypothesized to be measures of two correlated latent variables, SES and Educational Future. The head of household's occupational and educational levels and number of hours spent reading books to one's child are the observed measures of the former factor; parents' aspirations and expectations about the child's eventual educational achievement are observed measures of the latter factor. The model fits the observed data well ($X^2$=3.77, df=4, p=0.438).

The Year One model includes two correlated factors: Receptive Ability and Productive Ability. The two subtests of the Johns Hopkins Perceptual Test (Perception and Analysis) and the two Peabody Picture Vocabulary Test: Form A (Receptive) subtests, Nouns and Verbs, are measures of Receptive Ability. The two subtests of the Peabody Picture Vocabulary Test: Form B (Productive), Nouns and Verbs, are measures of Productive Ability. This model fits quite well ($X^2$=4.94, df=7, p=0.667).

The Year Two model is composed of two correlated latent variables, Verbal Ability and Perceptual Discrimination. The former has two observed variables: the Cooperative Preschool Test and the ETS Matched Picture Test. The two subtests from the Johns Hopkins Perceptual Test, Perception and Analysis, are observed measures of Perceptual Discrimination. The model has a marginally acceptable fit ($X^2$=3.71, df=1, p=0.054).

The Year Three model consists of three correlated latent abilities, Verbal, Visual, and Story Sequencing. Each of the observed variables was administered in Spring of the subjects' kindergarten year. The Word Meaning and Listening subtests of the Metropolitan Readiness Test are the manifest measures of Verbal Ability. The Matching, Alphabet, and Copying subtests are observed measures of Visual Ability. The Card Order and Fluency subtests of the ETS Story Sequence Task are the manifest measures of Story Sequencing. The model fits the observed data ($X^2$=16.82, df=11, p=0.113).

The longitudinal model which consists of reading achievement tests administered in the Spring of first, second, and third grades is different than those discussed to this point. It is a structural equation model. Accordingly, it includes both structural and measurement components. It includes two factors: Beginning Reading Achievement (Spring of grade one) and Intermediate Reading Achievement (Spring of grades two and three). Beginning Reading Achievement has two manifest variables, Reading and Word Analysis, which are subtests of the Cooperative Primary Tests administered in year four. The corresponding tests administered in years five and six, are the four observed measures of Intermediate Reading Achievement. (The Listening subtests did not fit well in the model, and were eliminated.) This model includes three correlated residual terms: the Reading subtests from years four and five, the year six subtests, and the year five Reading subtest with the year six Word Analysis subtest. The structural model includes a direct effect of Beginning Reading Achievement on Intermediate Reading Achievement. The model fits the observed data well ($X^2$=3.37, df=5, p=0.643).

### Cross-Sectional Models: Within-group Models

After cross-sectional confirmatory factor analysis models were developed for the sample as a whole, the three treatment groups were considered separately. Specifically, each of the five cross-sectional models discussed above (Parent

Interview, Year One, Year Two, Year Three, and Years Four, Five, and Six) was tested on each of the treatment groups. To make the data base more manageable, those subjects with a great deal of missing data were eliminated at this point in the analyses.

The fits of those models are presented in Table 2. The models generally fit the data of each treatment group. However, the Parent Interview model for the No Preschool sample did not converge and the Year One model did not fit the observed data of the same group. Furthermore, minor modifications were necessary in the reading achievement models: although all of the models included a subset of the three pairs of correlated residuals, none of the models included all three.

### Developing Criteria for Handling Missing Data

Next, the longitudinal nature of the data was considered using structural equation models. At this point, one might expect to merely combine the cross-sectional models and examine causal relationships among the latent variables within and between those models. Although that general strategy was eventually employed, first the problem of missing data had to be considered. In a project that attempts to follow hundreds of children in four locations for a period of six years, complete data cannot be expected. This is understandable considering children's school attendance, the mobility of families, and the administrative task of coordinating such a study. Some subjects in the study did have all observed variables of interest; unfortunately, a majority of subjects were missing data.

## Table 2
## Cross-Sectional Confirmatory Factor Analysis Models
## Goodness-of-Fit

| Model | Group | $\chi^2$ | df | p | N |
|---|---|---|---|---|---|
| Parent Interview | All | 3.77 | 4 | 0.438 | 1261 |
| | Head Start | 1.96 | 4 | 0.744 | 439 |
| | No Preschool | * | | | 195 |
| | Other Preschool | 2.78 | 4 | 0.596 | 193 |
| Year One | All | 4.94 | 7 | 0.667 | 514 |
| | Head Start | 7.37 | 7 | 0.391 | 279 |
| | No Preschool | 21.49 | 7 | 0.003 | 101 |
| | Other Preschool | 9.93 | 7 | 0.192 | 97 |
| Year Two | All | 3.71 | 1 | 0.054 | 1126 |
| | Head Start | 0.13 | 1 | 0.723 | 506 |
| | No Preschool | 1.89 | 1 | 0.169 | 170 |
| | Other Preschool | 1.73 | 1 | 0.189 | 181 |
| Year Three | All | 16.82 | 11 | 0.113 | 585 |
| | Head Start | 18.34 | 11 | 0.074 | 379 |
| | No Preschool | 8.09 | 11 | 0.706 | 101 |
| | Other Preschool | 7.76 | 11 | 0.734 | 68 |
| Years 4,5 & 6 | All | 3.37 | 5 | 0.643 | 954 |
| | Head Start | 11.97 | 7 | 0.101 | 393 |
| | No Preschool | 7.68 | 6 | 0.262 | 376 |
| | Other Preschool | 10.92 | 7 | 0.142 | 185 |

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* Note. Did not converge.

For that reason, decision rules were formulated to determine which subjects to include in subsequent analyses. One method of handling missing data, listwise deletion, excludes all subjects that do not have complete data. That approach was considered inappropriate because the resulting samples would include very few children. Furthermore, since it is unlikely that those with complete data are representative of the sample as a whole, alternatives were considered.

As an initial step, we examined frequency distributions of the number of missing variables in longitudinal models consisting of various combinations of the cross-sectional models. It was decided that each longitudinal model would be comprised of data from subjects missing a maximum of one variable, in each year included in that model. This criterion will be referred to as the "maximum missings" criterion. The resulting sample sizes for longitudinal models were then examined. Although it would be desireable to include observed measures of SES, pre-treatment readiness (year one), post-treatment readiness (years two[1] and three -- especially the commonly used measures such as the Metropolitan Readiness subtests), and reading achievement (years four, five, and six) all in one model, the limited longitudinal sample sizes forced us to consider other models of interest. The sample sizes for the various combinations of years are presented in Tables 3 and 4. (Note that two tables are presented because sample sizes, both with and without ETS Story Sequence Task, were considered.)

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[1] Note. As mentioned above, Head Start was attended in year two by all children in the study except those in Lee County, Alabama, where they attended in year three.

## Table 3
## Sample Sizes of Models that were Considered

| Cross-Sectional Models Included in the Select Criterion[1] | Head Start | No Preschool | Other Preschool |
|---|---|---|---|
| Parent Intvw., Years 1 2 3 4 5 6 | 106 | 23 | 16 |
| Parent Intvw., Years 1 2 3 4 5 | 128 | 28 | 16 |
| Parent Intvw., Years 1 2 3 4 6 | 110 | 23 | 16 |
| Parent Intvw., Years 1 2 3 4 | 160 | 41 | 23 |
| Parent Intvw., Years 1 2 3 5 | 129 | 28 | 16 |
| Parent Intvw., Years 1 2 3 6 | 111 | 23 | 16 |
| Parent Intvw., Years 2 3 4 5 6[2] | 219 | 49 | 29 |
| Parent Intvw., Years 2 3 4 | 315 | 77 | 42 |
| Parent Intvw., Years 2 3 5 | 257 | 63 | 31 |
| Parent Intvw., Years 2 3 6 | 226 | 51 | 30 |
| Parent Intvw., Years 3 4[3] | 344 | 106 | 52 |
| Parent Intvw., Years 3 5 | 282 | 82 | 40 |
| Parent Intvw., Years 3 6 | 249 | 63 | 36 |
| Parent Intvw., Years 1 4 | 220 | 70 | 65 |
| Parent Intvw., Years 1 5 | 177 | 47 | 50 |
| Parent Intvw., Years 1 6 | 146 | 36 | 46 |
| Parent Intvw., Years 2 3[4] | 349 | 102 | 62 |
| Parent Intvw., Years 2 4 | 407 | 112 | 137 |
| Parent Intvw., Years 2 5 | 332 | 97 | 117 |
| Parent Intvw., Years 2 6 | 284 | 80 | 112 |
| Parent Intvw., Years 5 6[5] | 300 | 117 | 128 |
| Years 1 2 5 | 177 | 43 | 46 |
| Years 1 2 6 | 144 | 34 | 43 |
| Years 1 3 6 | 123 | 23 | 20 |
| Years 2 3 6 | 252 | 55 | 33 |
| Years 2 4 | 454 | 119 | 142 |
| Years 2 5 | 377 | 106 | 122 |
| Years 2 6 | 319 | 85 | 115 |
| Years 3 4 | 417 | 112 | 59 |
| Years 3 5 | 354 | 89 | 47 |
| Years 3 6 | 310 | 67 | 43 |
| Years 3 4 5 6 | 297 | 64 | 42 |

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Notes. 1 The missing variables count, for year three, includes the ETS Story Sequence Task.

2 Adopted for LISREL analyses: Model One.

3 Adapted for LISREL analyses: Model Three.

4 Adopted for LISREL analyses: Model Two.

5 Adopted for LISREL analyses: Model Five.

## Table 4
## Sample Sizes of Models that were Considered

| Cross-Sectional Models Included in the Select Criterion[1] | Head Start | No Preschool | Other Preschool |
|---|---|---|---|
| Parent Intvw., Years 1 2 3 4 5 6 | 110 | 23 | 17 |
| Parent Intvw., Years 1 2 3 4 5 | 133 | 29 | 18 |
| Parent Intvw., Years 1 2 3 4 6 | 115 | 23 | 17 |
| Parent Intvw., Years 1 2 3 4 | 170 | 43 | 25 |
| Parent Intvw., Years 1 2 3 5 | 134 | 29 | 18 |
| Parent Intvw., Years 1 2 3 6 | 116 | 23 | 17 |
| Parent Intvw., Years 2 3 4 | 328 | 79 | 45 |
| Parent Intvw., Years 2 3 5 | 265 | 64 | 34 |
| Parent Intvw., Years 2 3 6 | 234 | 51 | 32 |
| Parent Intvw., Years 3 4 | 361 | 110 | 57 |
| Parent Intvw., Years 3 5 | 293 | 84 | 43 |
| Parent Intvw., Years 3 6 | 260 | 64 | 39 |
| Years 1 3 6 | 123 | 23 | 20 |
| Years 2 3 6 | 261 | 55 | 35 |
| Years 3 4 | 454 | 292 | 74 |
| Years 3 5 | 385 | 267 | 60 |
| Years 3 6 | 331 | 197 | 55 |
| Years 3 4 5 6[2] | 316 | 188 | 51 |

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[1] Notes. The missing variables count, for year three, does not include the ETS Story Sequence Task.

[2] Adopted for LISREL analysis: Model Four

Examination of the sample sizes resulted in the selection of five models to be tested:

Model One: Parent Interview and Years Two through Six
Model Two: Parent Interview, Years Two and Three
Model Three: Parent Interview and Years Three and Four
Model Four: Years Three through Six
Model Five: Parent Interview and Years Five and Six.

In order to conduct analyses on each of those five models, two preliminary steps were taken for each of the five models. First, subjects were selected that met the "maximum missings" criterion for the particular model. The resulting univariate summary statistics, for the variables in each model, are presented in Appendices D.1 through D.5. (A legend of the variable names is presented in Appendix D.6.) Second, within-group means and covariances were estimated. A LISREL VI analysis requires a positive definite variance/covariance matrix. Orchard and Woodbury (1972) present a method for imputing missing values, which is incorporated in BMDP program AM5 (Frane, 1983). Essentially, it uses a regression approach to this problem. In separate analyses, each variable is regressed on all other variables. In this way, missing values are imputed based on the relationships among the variables. The resulting variance/covariance matrix is positive-definite and, therefore, meets that assumption of LISREL VI. The estimated within-group covariance matrices, for each of the five models, are presented in Appendices E.1 through E.5.

A different combination of variables is included in each model. Consequently, some subjects are not included in any of the models. Data from some subjects are included in the covariance matrix of just one model; data from other subjects are included in more than one model. Table 5 presents the pattern of overlap of subjects in the models. For example, in the models for the Head Start group, although 32 subjects were only in Model Two, 96 subjects were in Models Two and Three, but no other models. To determine how many subjects were included in testing Model Two for the Head Start group, we add the 32 in Model Two only, the 96 in Models Two and Three, the two in Models Two and Four, and the 219 in all Models. The sum, 349, is the number of subjects from the Head Start group that were in Model Two.

In order to explore possible patterns of missing data, we examined cross-tabulations of the patterns of overlap with variables such as treatment and SES.No obvious patterns emerged. Consequently, we conducted the analyses as if the data were missing at random.

### Structural Equation Models

The factor patterns of the cross-sectional confirmatory factor analyses were generally maintained, and causal relationships among the latent variables were tested in each of the five models. Attempts to fit the models made it clear that modifications in parameter specifications, and even deletion of some observed variables, were necessary. For instance, the SES component of the longitudinal models fit better with the deletion of the parent interview item regarding the number of hours that the parents read to the child. Also, although the results of the examination of longitudinal sample sizes allowed for the inclusion of the ETS Story Sequence subtests in Models Two and Three, problems with convergence of those models led to the deletion of those two variables.

The five models presented below include subsets of eight latent variables (and the corresponding observed measures that have been presented): two home background factors, two pre-readiness factors, two reading readiness factors, one beginning reading achievement factor and one intermediate reading achievement

## Table 5
## Pattern of Overlap of Subjects in Models

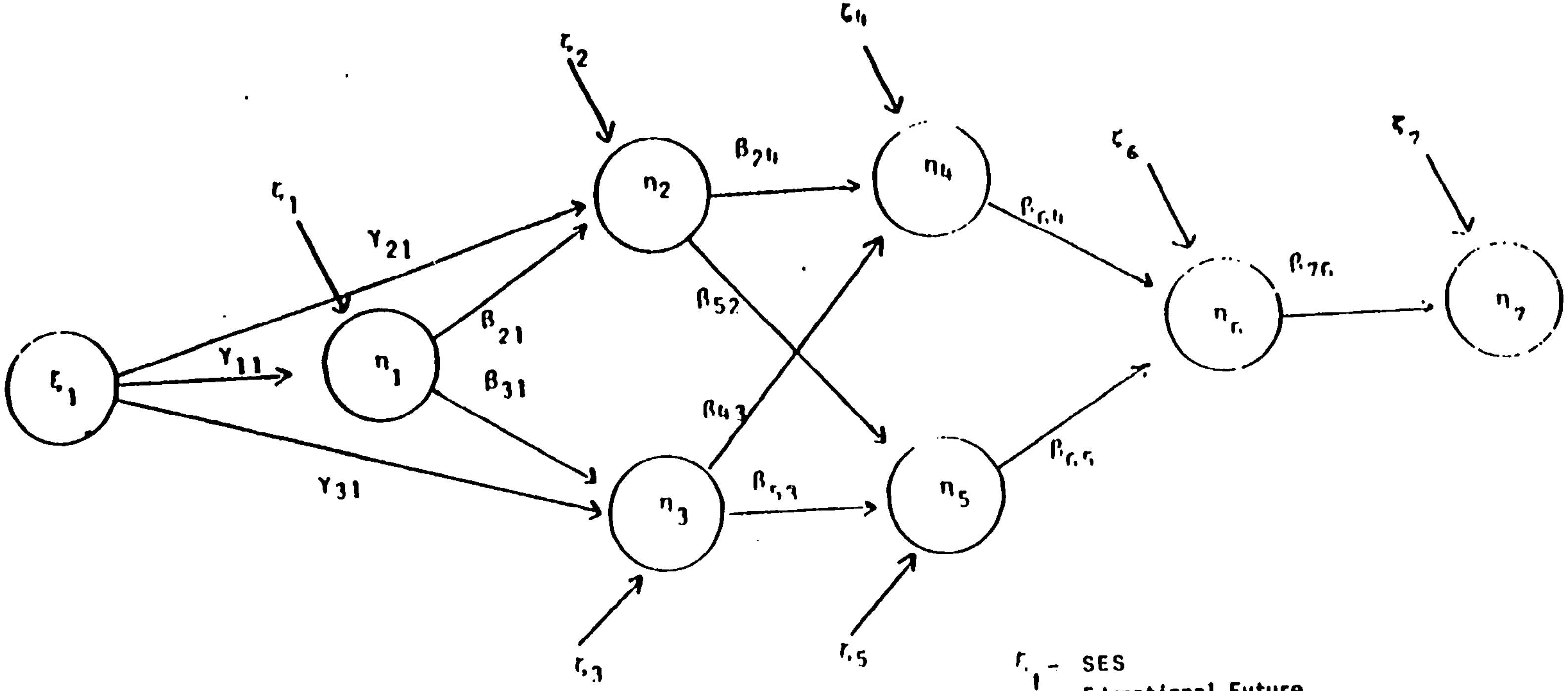
| Model Numbers | Frequency | Percent |
|---|---|---|
| | **Head Start Group** | |
| None | 147 | 22.5 |
| Two | 32 | 4.9 |
| Three | 9 | 1.4 |
| Four | 64 | 9.8 |
| Five | 51 | 7.8 |
| Two and three | 96 | 14.7 |
| Two and four | 2 | 0.3 |
| Four and five | 6 | 0.9 |
| One, four, and five | 7 | 1.1 |
| Three, four, and five | 20 | 3.1 |
| All | 219 | 33.5 |
| TOTAL | 653 | 100.0 |
| | **No Preschool Group** | |
| None | 367 | 54.0 |
| Two | 24 | 3.5 |
| Three | 17 | 2.5 |
| Four | 125 | 18.4 |
| Five | 55 | 8.1 |
| Two and three | 28 | 4.1 |
| Two and five | 1 | 0.1 |
| Four and five | 2 | 0.3 |
| Three, four, and five | 12 | 1.8 |
| All | 49 | 7.2 |
| TOTAL | 680 | 100.0 |

factor. A general structural model, which incorporates all eight latent variables, was developed as a guide intended to determine which structural parameters to include in each of the five models. This general model is presented in Figure 10.

Initially theoretical ideas and time of measurement were used to select causal paths in the general structural model. Each latent variable from one point in time was hypothesized to affect all latent variables at the next point in time, but no others. The one within-year effect that was included was the effect of SES on Educational Future. This general structural model was used as the basic design for causal relationships in Models One through Five.

The five models were then considered separately. To develop each structural model, the latent variables from the general model that comprised the particular model were considered, and corresponding structural parameters estimated. Structural parameters were added to or deleted from each model when it was considered necessary. More specifically, causal paths were eliminated based on the significance levels of the parameter estimates. The non-significant parameters were fixed at zero individually, in a stepwise process. The fit of each restricted model was compared with that of the previous model to make sure that the fit was no worse. In this way, for example, the effects of Perceptual Discrimination on each of the Year Three factors, that were hypothesized in the general structural model, were eliminated from Models One and Two.

In some cases, within-year causal paths that were originally fixed at zero were freed (to be estimated). This was done only if both the causal relationship was theoretically plausible and the modification indices of the more restricted



$\xi_1$ - SES
$\eta_1$ - Educational Future
$\eta_2$ = Verbal Ability
$\eta_3$ = Perceptual Discrimination
$\eta_4$ = Verbal Readiness
$\eta_5$ - Visual Readiness
$\eta_6$ - Beginning Reading Achievement
$\eta_7$ - Intermediate Reading Achievement

Figure 10. General Structural Model: Parent Interview and Years Two through Six

model indicated that a significant difference in fit would result. Consequently, two within-year effects were added to those included in the general structural model: the effect of Verbal Ability on Perceptual Discrimination and that of Verbal Readiness on Visual Readiness. The structural components of each of the models will be discussed in detail in the following sections. In addition, any modifications of the measurement models presented earlier will be mentioned. The fits of the models are summarized in Table 6.

### Model One: Parent Interview and Years Two through Six

The discussion begins with the most elaborate of the structural models, Model One. It includes the latent variables from all of the cross-sectional models except year one. (Year one variables are not included in any of the longitudinal models because of small sample sizes.) In this case, there is a trade-off between number of variables and number of groups. This comprehensive includes eight latent variables, and nineteen observed measures that span six years. Because selection was based on the "maximum-missings" criterion, only the Head Start group had the minimum of 100 subjects desireable for model testing. (The remaining models were tested on both the Head Start and No Preschool groups.) The model is illustrated in Figure 11. The maximum-likelihood estimates are presented in Table 7. The Head Start sample includes 226 children.

In this model SES directly influences Educational Future which affects both Verbal Ability and Perceptual Discrimination. Verbal Ability influences Visual Readiness directly, and indirectly through Verbal Readiness. Visual Readiness influences Beginning Reading Achievement, which in turn directly affects Intermediate Reading Achievement. As mentioned above, the effects of

Table 6
Longitudinal Models: Goodness-of-Fit

| Model | Years | Group | $\chi^2$ | df | p | N |
|---|---|---|---|---|---|---|
| One | PI[3], 2 - 6 | Head Start | 153.37 | 139 | 0.191 | 226 |
| Two | PI, 2 & 3 | Head Start | 73.05 | 56 | 0.063 | 349 |
| | | No Preschool | 63.14 | 59 | 0.332 | 102 |
| Three | PI, 3 & 4 | Head Start | 52.60 | 39 | 0.072 | 344 |
| | | No Preschool | 52.75 | 40 | 0.085 | 106 |
| Four | 3 4 5 & 6 | Head Start | 36.43 | 35 | 0.402 | 316 |
| | | No Preschool | 48.93 | 37 | 0.091 | 188 |
| Five | PI, 5 & 6 | Head Start | | | | 305 |
| | | No Preschool | | | | 119 |
| $H_0$ | Equal factor loadings (LY=IN) | | 32.40 | 21 | 0.053 | |
| $H_1$ | No initial differences (and LY=IN) | | 55.57 | 22 | 0.000 | |
| $H_2$ | Parallel slopes (and LY=IN) | | 32.76 | 22 | 0.065 | |
| $H_3$ | No outcome differences controlling for initial differences (and LY=IN) | | 33.23 | 23 | 0.077 | |

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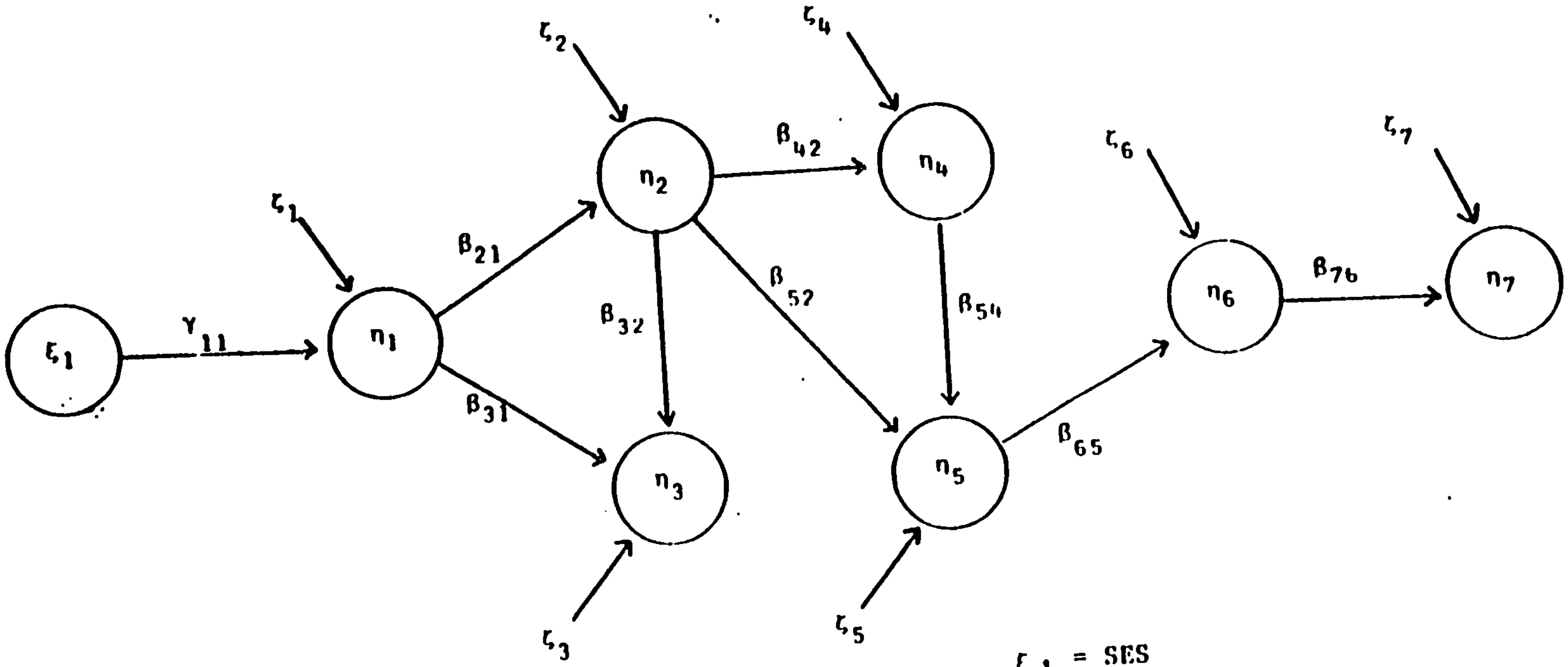
[3] Parent Interview



$\xi_1$ = SES
$\eta_1$ = Educational Future
$\eta_2$ = Verbal Ability
$\eta_3$ = Perceptual Discrimination
$\eta_4$ = Verbal Readiness
$\eta_5$ = Visual Readiness
$\eta_6$ = Beginning Reading Achievement
$\eta_7$ = Intermediate Reading Achievement

Figure 11. Parent Interview and Years Two through Six

## Table 7

## Model One: Parent Interview and Years One through Six -- Head Start Group

## LISREL Estimates (Maximum Likelihood)

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 | ETA 6 | ETA 7 |
|---|---|---|---|---|---|---|---|
| SES3 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| SES4 | 1.082 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| CLD201 | 0.000 | 4.455 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| PIC209 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| JHP201 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| JHP202 | 0.000 | 0.000 | 0.802 | 0.000 | 0.000 | 0.000 | 0.000 |
| MET301 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 |
| MET302 | 0.000 | 0.000 | 0.000 | 1.010 | 0.000 | 0.000 | 0.000 |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 1.425 | 0.000 | 0.000 |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.857 | 0.000 | 0.000 |
| CPT401 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 |
| CPT403 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.357 | 0.000 |
| CPT501 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| CPT503 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.883 |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.225 |
| CPT603 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.377 |

LAMBDA X

| | KSI 1 |
|---|---|
| SES11 | -0.928 |
| SES12 | 2.176 |

Table 7 (continued)

BETA

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 | ETA 6 | ETA 7 |
|---|---|---|---|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 1.497 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 3 | -0.985 | 1.029 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 4 | 0.000 | 0.490 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 5 | 0.000 | 0.463 | 0.000 | 0.437 | 0.000 | 0.000 | 0.000 |
| ETA 6 | 0.000 | 0.000 | 0.000 | 0.000 | 1.015 | 0.000 | 0.000 |
| ETA 7 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.925 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | 0.896 |
| ETA 2 | 0.000 |
| ETA 3 | 0.000 |
| ETA 4 | 0.000 |
| ETA 5 | 0.000 |
| ETA 6 | 0.000 |
| ETA 7 | 0.000 |

PHI

| | KSI 1 |
|---|---|
| KSI 1 | 1.000 |

PSI

| ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 | ETA 6 | ETA 7 |
|---|---|---|---|---|---|---|
| 0.300 | 2.513 | 0.865 | 3.384 | 2.112 | 2.190 | 4.719 |

Table 7 (continued)

THETAEPS

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | | MET306 | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 3.272 | | | | | | | | | | | | | | | | |
| SES4 | 0.806 | 2.165 | | | | | | | | | | | | | | | |
| CLD201 | 0.000 | 0.000 | 23.640 | | | | | | | | | | | | | | |
| PIC209 | 0.000 | 0.000 | 0.000 | 4.577 | | | | | | | | | | | | | |
| JHP201 | 0.000 | 0.000 | 0.000 | 0.000 | 2.908 | | | | | | | | | | | | |
| JHP202 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.638 | | | | | | | | | | | |
| MET301 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.556 | | | | | | | | | | |
| MET302 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.194 | | | | | | | | | |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 6.729 | | | | | | | | |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 14.429 | | | | | | | |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.463 | | | | | | |
| CPT401 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 77.529 | | | | | |
| CPT403 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 37.195 | 67.865 | | | | |
| CPT501 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 34.400 | | | |
| CPT503 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 46.533 | | |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 85.717 | |
| CPT603 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | -17.824 | 0.000 | 60.256 | 171.668 |

THETADELTA

| SES11 | SES12 |
|---|---|
| 3.929 | 4.859 |

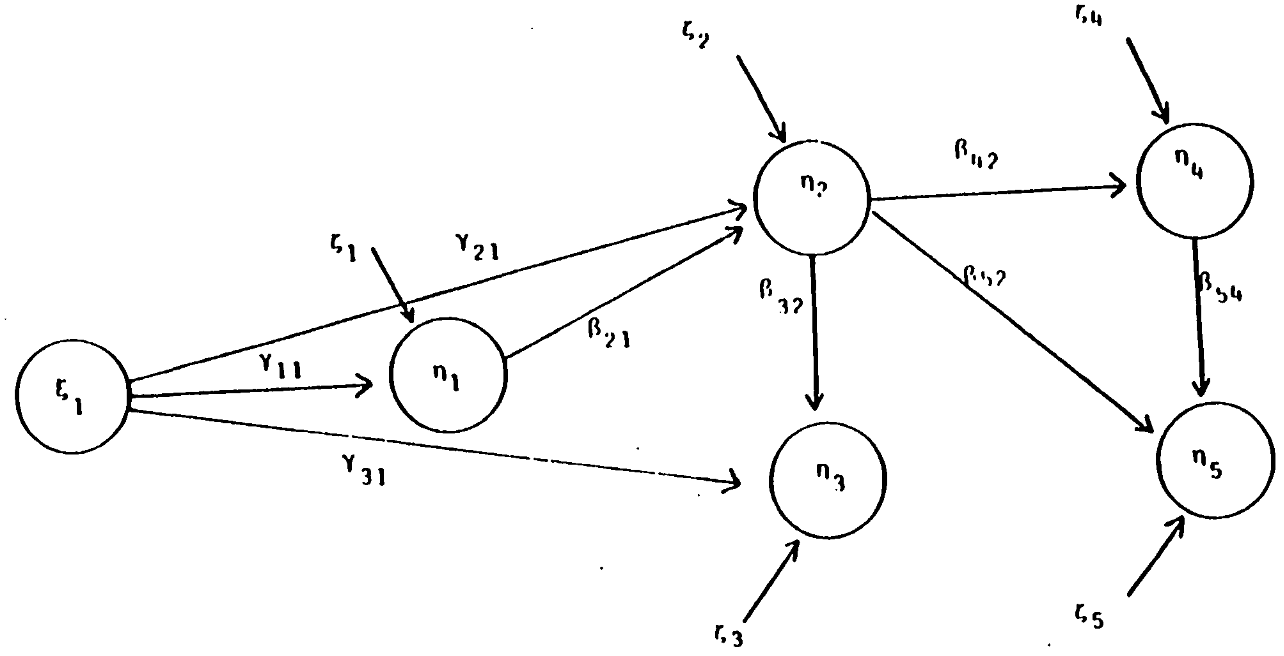
Chi-square with 139 degrees of freedom is 153.37 ($p=0.191$).

Perceptual Discrimination that were hypothesized in the general model were not significant and, therefore, deleted. In addition, three other direct effects, which were included in the general structural model, were not significant and fixed at zero: the influence of SES on both Verbal Ability and Perceptual Discrimination and the effect of Verbal Readiness on Beginning Reading Achievement.

The measurement models are consistent with those presented above. Additionally, there are four pairs of correlated residuals. They include correlations between the two observed measures of Educational Future, the two observed measures of Beginning Reading Achievement, the two year six measures of Intermediate Reading Achievement, and the year five Reading subtest and the year six Word Analysis subtest. The first three of those are more understandable than the last one. These correlated residuals substantially improve the fit. The chi-square without any of the four is 287.54 with 143 degrees of freedom. Freeing the first three correlated residuals results in a chi-square of 198.13 with 140 degrees of freedom ($\underline{p}$ = 0.001). The correlation between year five Reading and year six Word Analysis residuals is significantly different from zero ($\underline{t}$=-3.473), but freeing it does not change either the structural parameters or factor loadings much. (Differences in those parameters are generally in the second or third decimal place.) The model fits the observed data reasonably well ($X^2$=153.37, df=139, $\underline{p}$=0.191).

**Model Two: Parent Interview and Years Two and Three**

Model Two is less comprehensive. It does not include any reading achievement factors. It includes six latent variables, those from the Parent Interview, Year Two, and Year Three cross-sectional models. The model is presented in Figure 12. The maximum-likelihood estimates are presented in Table 8. The Head Start and No Preschool samples include 349 and 102 children,



$\xi_1$ = SES
$\eta_1$ = Educational Future
$\eta_2$ = Verbal Ability
$\eta_3$ = Perceptual Discrimination
$\eta_4$ = Verbal Readiness
$\eta_5$ = Visual Readiness

Figure 12. Model Two: Parent Interview and Years Two and Three

## Table 8

## Model Two: Parent Interview and Years Two and Three -- Head Start Group

## LISREL Estimates (Maximum Likelihood)

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| SES3 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| SES4 | 1.130 | 0.000 | 0.000 | 0.000 | 0.000 |
| CLD201 | 0.000 | 5.213 | 0.000 | 0.000 | 0.000 |
| PIC209 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 |
| JHP201 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 |
| JHP202 | 0.000 | 0.000 | 0.776 | 0.000 | 0.000 |
| MET301 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 |
| MET302 | 0.000 | 0.000 | 0.000 | 1.070 | 0.000 |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 1.520 |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.752 |

LAMBDA X

| | KSI 1 |
|---|---|
| SES11 | 0.835 |
| SES12 | -2.246 |

BETA

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 1.380 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.914 | 0.000 | 0.000 | 0.000 |
| ETA 4 | 0.000 | 0.506 | 0.000 | 0.000 | 0.000 |
| ETA 5 | 0.000 | 0.524 | 0.000 | 0.522 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | -0.741 |
| ETA 2 | 0.000 |
| ETA 3 | 0.476 |
| ETA 4 | 0.000 |
| ETA 5 | 0.000 |

Table 8 (continued)

PSI

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| ETA 1 | 0.577 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 0.000 | 2.241 | 0.000 | 0.000 | 0.003 |
| ETA 3 | 0.000 | 0.000 | 1.438 | 0.000 | 0.000 |
| ETA 4 | 0.000 | 0.000 | 0.000 | 2.789 | 0.000 |
| ETA 5 | 0.000 | 0.000 | 0.000 | 0.000 | 2.387 |

THETA EPS

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | MET304 | MET306 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 3.215 | | | | | | | | | | |
| SES4 | 0.325 | 2.531 | | | | | | | | | |
| CLD201 | 0.000 | 0.000 | 20.995 | | | | | | | | |
| PIC209 | 0.000 | 0.000 | 0.000 | 4.995 | | | | | | | |
| JHP201 | 0.000 | 0.000 | 0.000 | 0.000 | 2.670 | | | | | | |
| JHP202 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.488 | | | | | |
| MET301 | 0.000 | 0.000 | 0.233 | 0.000 | 0.000 | 0.000 | 5.438 | | | | |
| MET302 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.141 | | | |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 6.472 | | |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 12.989 | |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.085 |

THETA DELTA

| SES11 | SES12 |
|---|---|
| 4.774 | 3.923 |

Chi-square with 56 degrees of freedom is 73.05 (*p* = 0.063)

Table 8 (continued)

Model Two: Parent Interview and Years Two and Three -- No Preschool Group

LISREL Estimates (Maximum Likelihood)

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| SES3 | 1.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| SES4 | 1.958 | 0.000 | 0.000 | 0.000 | 0.000 |
| CLD201 | 0.000 | 4.267 | 0.000 | 0.000 | 0.000 |
| PIC209 | 0.000 | 1.000 | 0.000 | 0.000 | 0.000 |
| JHP201 | 0.000 | 0.000 | 1.000 | 0.000 | 0.000 |
| JHP202 | 0.000 | 0.000 | 0.443 | 0.000 | 0.000 |
| MET301 | 0.000 | 0.000 | 0.000 | 1.000 | 0.000 |
| MET302 | 0.000 | 0.000 | 0.000 | 1.026 | 0.000 |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 1.373 |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.834 |

LAMBDA X

| | KSI 1 |
|---|---|
| SES11 | 2.360 |
| SES12 | -2.004 |

BETA

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.623 | 0.000 | 0.000 | 0.000 |
| ETA 4 | 0.000 | 0.350 | 0.000 | 0.000 | 0.000 |
| ETA 5 | 0.000 | 1.187 | 0.000 | 0.229 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | -0.417 |
| ETA 2 | -0.961 |
| ETA 3 | 0.000 |
| ETA 4 | 0.000 |
| ETA 5 | 0.000 |

Table 8 (continued)

PSI

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 | ETA 5 |
|---|---|---|---|---|---|
| ETA 1 | 0.341 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 0.000 | 2.726 | 0.000 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.000 | 4.347 | 0.000 | 0.000 |
| ETA 4 | 0.000 | 0.000 | 0.000 | 11.958 | 0.000 |
| ETA 5 | 0.000 | 0.000 | 0.000 | 0.000 | 0.889 |

THETA EPS

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | MET304 | MET306 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 3.291 | | | | | | | | | | |
| SES4 | 0.000 | 0.679 | | | | | | | | | |
| CLD201 | 0.000 | 0.000 | 41.913 | | | | | | | | |
| PIC209 | 0.000 | 0.000 | 0.000 | 5.249 | | | | | | | |
| JHP201 | 0.000 | 0.000 | 0.000 | 0.000 | 0.001 | | | | | | |
| JHP202 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.434 | | | | | |
| MET301 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 3.988 | | | | |
| MET302 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.286 | | | |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 6.964 | | |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 16.403 | |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.973 |

THETA DELTA

| SES11 | SES12 |
|---|---|
| 3.127 | 3.306 |

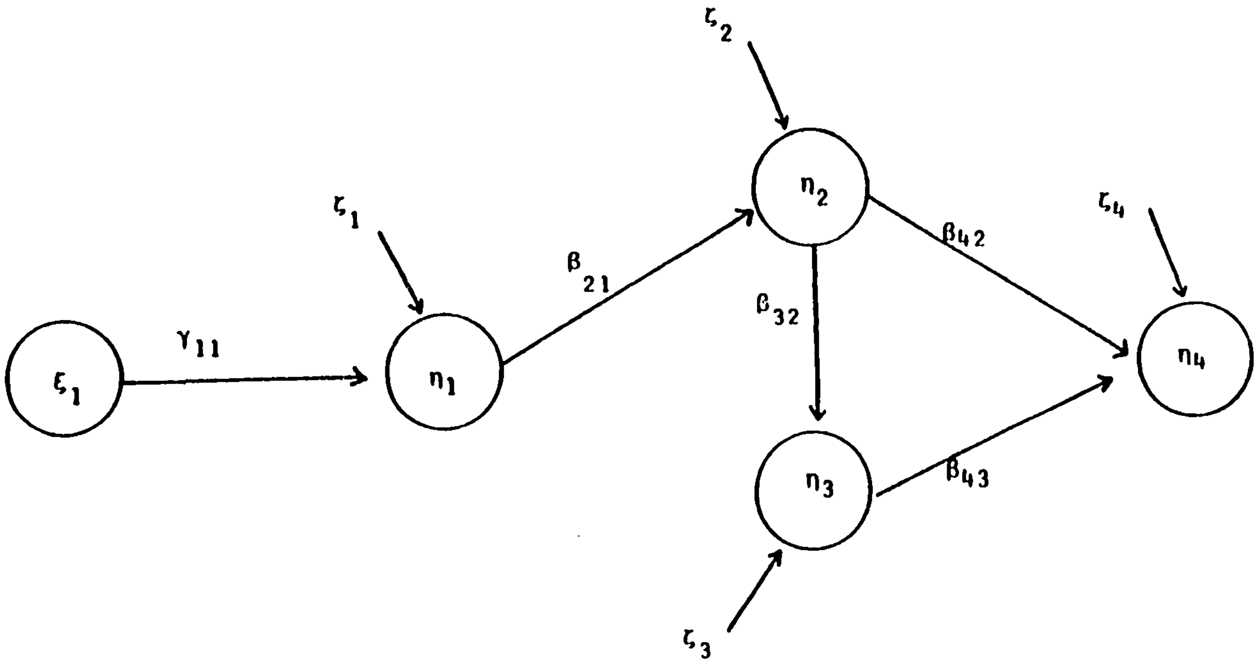
Chi-square with 59 degrees of freedom is 63.14 (*p* = 0.332) respectively. SES influences Educational Future, which in turn affects Verbal Ability. SES also directly influences Perceptual Discrimination. These last two effects are not included in the model for the No Preschool group. (The influence of SES on Verbal Ability is direct in the model for that group.) The causal structure of the remainder of the model is similar across groups. Verbal Ability influences Perceptual Discrimination, which does not influence other factors. Verbal Ability also affects Visual Readiness, both directly, and indirectly through Verbal Readiness. In the model for the No Preschool group the influence of Verbal Ability on Verbal Readiness is not significant, but is included for identification. As mentioned earlier, the effects of Perceptual Discrimination on each of the year three factors, that were hypothesized in the general model, were deleted. In addition to those, the models for each group differ from the general structural model in two ways. In both models, the direct effect of Educational Future on Perceptual Discrimination has been deleted. In the model for the Head Start group, the direct effect of SES on Verbal Ability has been deleted. In the model for the No Preschool group, the direct effect of SES on Perceptual Discrimination has been deleted.

The model for the Head Start group includes two correlated residual terms: one between Educational Aspirations and Expectations and the other between the Metropolitan Readiness subtest, Listening and the Cooperative Preschool Test. The former of these is only marginally significant ($t=1.954$). Without the correlated residuals the model does not fit the data ($X^2=87.32$, df=58, $p=0.008$). However, by including them the model for the Head Start group has a marginally acceptable fit ($X^2=73.05$, df=56, $p=0.063$). Most structural parameters changed very little, with the exception of $\beta_{21}$. Not only did the signs of the parameters not differ with the inclusion of the correlated residuals, but whether or not they were significant did not change. Consequently, the interpretation of the model did not change. The model for the No Preschool group is a very good fit ($X^2$=63.14, df=59, p=0.332). Special parameterization techniques (Rindskopf, 1983) were applied to Model Two to correct problems with negative variance estimates.

### Model Three: Parent Interview and Years Three and Four

Model Three includes latent traits of home background, readiness, and reading achievement. The model is presented in Figure 13. The Head Start and No Preschool samples include 344 and 106 subjects, respectively. The maximum-likelihood estimates are presented in Table 9. SES directly influences Educational Future, which directly affects Verbal Readiness. Verbal Readiness affects Visual Readiness. In the model for the Head Start group, each of these factors has a non-significant effect on Beginning Reading Achievement, but is needed for identification. The non-significant influence of Visual Readiness on Beginning Reading Achievement is inconsistent with that hypothesized in the general structural model. The two observed measures of Educational Future have correlated residuals. That model has a marginally acceptable fit ($X^2$=52.60, df=39, p=0.072). An attempt to fit the model without the correlated residuals resulted in a non-convergent solution.

The model for the No Preschool group has similar parameter specifications, but does not include any correlated residuals. The non-significant parameters differ. The effect of SES on Educational Future and, in turn, its effect on Verbal Readiness are not significant, but they are needed for identification. The former of these is inconsistent with the general structural model. The fit of the model is acceptable ($X^2$=52.75, df=40, p=0.085). Because of negative estimates,



**$\xi_1$ = SES**
**$\eta_1$ = Educational Future**
**$\eta_2$ = Verbal Readiness**
**$\eta_3$ = Visual Readiness**
**$\eta_4$ = Beginning Reading Achievement**

Figure 13. Model Three: Parent Interview and Years Three and Four

Table 9

**Model Three: Parent Interview and Years Three and Four**

**LISREL Estimates (Maximum Likelihood)**

Head Start Group

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| SES3 | 1.000 | 0.000 | 0.000 | 0.000 |
| SES4 | 1.039 | 0.000 | 0.000 | 0.000 |
| MET301 | 0.000 | 1.000 | 0.000 | 0.000 |
| MET302 | 0.000 | 1.112 | 0.000 | 0.000 |
| MET303 | 0.000 | 0.000 | 1.000 | 0.000 |
| MET304 | 0.000 | 0.000 | 1.436 | 0.000 |
| MET306 | 0.000 | 0.000 | 0.788 | 0.000 |
| CPT401 | 0.000 | 0.000 | 0.000 | 1.000 |
| CPT403 | 0.000 | 0.000 | 0.000 | 2.129 |

LAMBDA X

| | KSI 1 |
|---|---|
| SES11 | 0.727 |
| SES12 | -2.277 |

BETA

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 0.464 | 0.000 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 1.641 | 0.000 | 0.000 |
| ETA 4 | 0.000 | -9.176 | 6.342 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | -0.820 |
| ETA 2 | 0.000 |
| ETA 3 | 0.000 |
| ETA 4 | 0.000 |

PHI

| | KSI 1 |
|---|---|
| KSI 1 | .000 |

Table 9 (continued)

PSI

|  | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| ETA 1 | 0.648 |  |  |  |
| ETA 2 | 0.000 | 1.616 |  |  |
| ETA 3 | 0.000 | 0.000 | 0.519 |  |
| ETA 4 | 0.000 | 0.000 | 0.000 | 3.577 |

THETA EPS

|  | SES3 | SES4 | MET301 | MET302 | MET303 | MET304 | MET306 | CPT401 | CPT403 |
|---|---|---|---|---|---|---|---|---|---|
| SES3 | 2.213 |  |  |  |  |  |  |  |  |
| SES4 | 0.000 | 1.602 |  |  |  |  |  |  |  |
| MET301 | 0.000 | 0.000 | 7.642 |  |  |  |  |  |  |
| MET302 | 0.000 | 0.000 | 2.174 | 6.278 |  |  |  |  |  |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 6.035 |  |  |  |  |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 14.538 |  |  |  |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.627 |  |  |
| CPT401 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 59.870 |  |
| CPT403 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.010 |

THETA DELTA

| SES11 | SES12 |
|---|---|
| 4.449 | 3.596 |

Chi-square with 39 degrees of freedom is 52.59 ($p = 0.072$)

Table 9 (continued)

Model Three: Parent Interview and Years Three and Four

LISREL Estimates (Maximum Likelihood)

No Preschool Group

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| SES3 | 1.000 | 0.000 | 0.000 | 0.000 |
| SES4 | 2.482 | 0.000 | 0.000 | 0.000 |
| MET301 | 0.000 | 1.000 | 0.000 | 0.000 |
| MET302 | 0.000 | 1.326 | 0.000 | 0.000 |
| MET303 | 0.000 | 0.000 | 1.000 | 0.000 |
| MET304 | 0.000 | 0.000 | 1.018 | 0.000 |
| MET306 | 0.000 | 0.000 | 0.594 | 0.000 |
| CPT401 | 0.000 | 0.000 | 0.000 | 1.000 |
| CPT403 | 0.000 | 0.000 | 0.000 | 1.568 |

LAMBDA X

| | KSI 1 |
|---|---|
| SES11 | 1.816 |
| SES12 | -1.820 |

BETA

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 1.288 | 0.000 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.527 | 0.000 | 0.000 |
| ETA 4 | 0.000 | -0.861 | 1.427 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | -0.339 |
| ETA 2 | 0.000 |
| ETA 3 | 0.000 |
| ETA 4 | 0.000 |

PHI

| | KSI 1 |
|---|---|
| KSI 1 | .000 |

Table 9 (continued)

PSI

| | ETA 1 | ETA 2 | ETA 3 | ETA 4 |
|---|---|---|---|---|
| ETA 1 | 0.071 | | | |
| ETA 2 | 0.000 | 8.029 | | |
| ETA 3 | 0.000 | 0.000 | 7.258 | |
| ETA 4 | 0.000 | 0.000 | 0.000 | 45.498 |

THETA EPS

| | SES3 | SES4 | MET301 | MET302 | MET303 | MET304 | MET306 | CPT401 | CPT403 |
|---|---|---|---|---|---|---|---|---|---|
| SES3 | 5.073 | | | | | | | | |
| SES4 | 0.000 | 1.560 | | | | | | | |
| MET301 | 0.000 | 0.000 | 6.443 | | | | | | |
| MET302 | 0.000 | 0.000 | 0.000 | 0.010 | | | | | |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 4.032 | | | | |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 17.212 | | | |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.506 | | |
| CPT401 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 50.063 | |
| CPT403 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 12.707 |

THETA DELTA

| SES11 | SES12 |
|---|---|
| 4.152 | 3.394 |

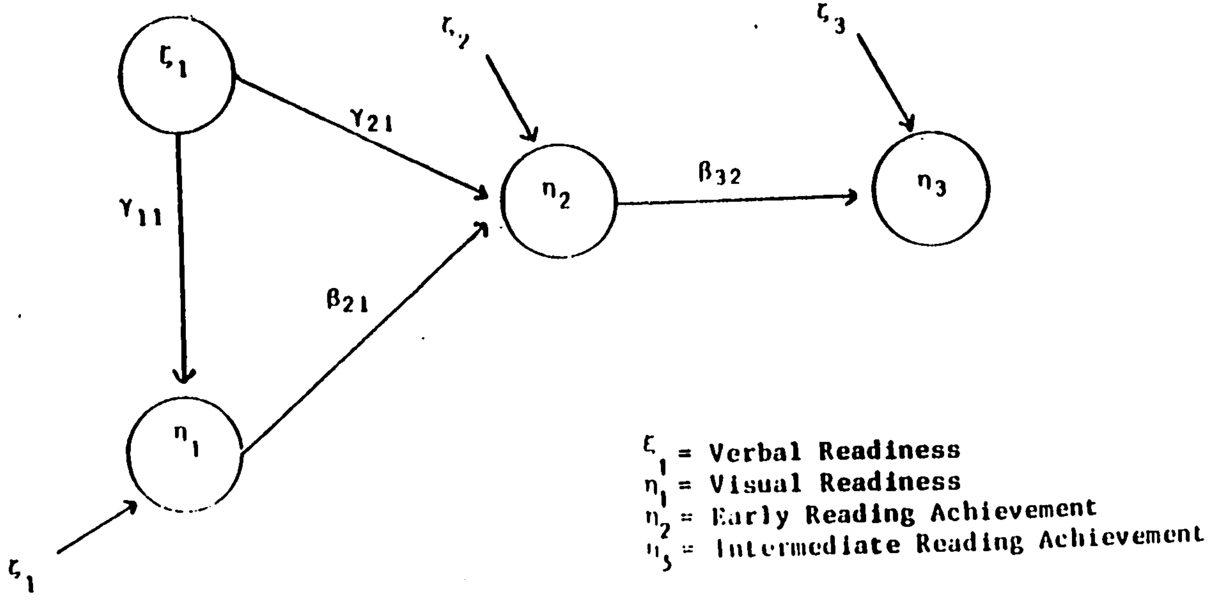
Chi-square with 40 degrees of freedom is 52.75 (*p* = 0.085).

the variances of one error term in each model was fixed at 0.01. (Attempts to constrain these variances greater than or equal to zero resulted in non-convergent solutions.)

**Model Four: Years Three through Six**

Model Four incorporates only the post-treatment latent variables. The model is presented in Figure 14. The maximum likelihood estimates are presented in Table 10. The Head Start and No Preschool samples include 316 and 188 children, respectively. The observed measures were administered in the four consecutive Springs, from kindergarten through third grade. Consequently, the model includes two readiness factors and both the reading achievement factors. Verbal Readiness directly influences both Visual Readiness and Beginning Reading Achievement. Beginning Achievement influences Intermediate Reading Achievement. In the model for the No Preschool group, the influence of Verbal readiness on Beginning Reading Achievement is not direct, but mediated by Visual Readiness. A direct effect of Verbal Readiness on Beginning Readiness Achievement was hypothesized in the general structural model.

The models include several correlated residuals. The following pairs of variables have correlated residuals in the model for the Head Start group: both observed measures from year four, both observed measures from year six, Word Analysis administered in years four and five, and Reading from year five and Word Analysis from year six and Listening and Copying from the Metropolitan Readiness Test. Without the correlated residuals the model does not fit the observed data ($X^2$=185.58, df=40, $p < 0.001$). However, by including those parameters, the model fits very well ($X^2$=36.43, df=35, $p$=0.402). Most parameters changed very little, with the exception of $\beta_{32}$ and $\gamma_{21}$. Not only did the signs



$\xi_1$ = Verbal Readiness
$\eta_1$ = Visual Readiness
$\eta_2$ = Early Reading Achievement
$\eta_3$ = Intermediate Reading Achievement

Figure 14. Model Four: Years Three, Four, Five, and Six

## Table 10

## Model Four: Years Three through Six

## LISREL Estimates (Maximum Likelihood)

Head Start Group

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| MET303 | 1.000 | 0.000 | 0.000 |
| MET304 | 1.527 | 0.000 | 0.000 |
| MET306 | 0.760 | 0.000 | 0.000 |
| CPT401 | 0.000 | 1.000 | 0.000 |
| CPT403 | 0.000 | 1.966 | 0.000 |
| CPT501 | 0.000 | 0.000 | 1.000 |
| CPT503 | 0.000 | 0.000 | 1.669 |
| CPT601 | 0.000 | 0.000 | 1.156 |
| CPT603 | 0.000 | 0.000 | 1.387 |

LAMBDA X

| | KSI 1 |
|---|---|
| MET301 | 2.367 |
| MET302 | 2.421 |

BETA

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 1.611 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 1.623 | 0.000 |

GAMMA

| | KSI 1 |
|---|---|
| ETA 1 | 0.513 |
| ETA 2 | -1.275 |
| ETA 3 | 0.000 |

Table 10 (continued)

PHI

|  | KSI 1 |
|---|---|
| KSI 1 | .000 |

PSI

| ETA 1 | ETA 2 | ETA 3 |
|---|---|---|
| 2.747 | 1.645 | 8.008 |

THETA EPS

|  | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 | MET303 | MET304 | MET306 |
|---|---|---|---|---|---|---|---|---|---|
| CPT401 | 72.647 |  |  |  |  |  |  |  |  |
| CPT403 | 34.847 | 70.571 |  |  |  |  |  |  |  |
| CPT501 | 0.000 | 0.000 | 30.443 |  |  |  |  |  |  |
| CPT503 | 0.000 | 11.919 | 0.000 | 64.559 |  |  |  |  |  |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 70.395 |  |  |  |  |
| CPT603 | 0.000 | 0.000 | -19.574 | 0.000 | 42.409 | 137.413 |  |  |  |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 7.257 |  |  |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 13.081 |  |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.224 | 0.000 | 5.951 |

THETA DELTA

| MET301 | MET302 |
|---|---|
| 4.867 | 3.723 |

Chi-square with 35 degrees of freedom is 36.43 (p = 0.402).

Table 10 (continued)

Model Four: Years Three through Six

LISREL Estimates (Maximum Likelihood)

No Preschool Group

LAMBDA Y

|  | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| MET303 | 1.000 | 0.000 | 0.000 |
| MET304 | 1.467 | 0.000 | 0.000 |
| MET306 | 0.668 | 0.000 | 0.000 |
| CPT401 | 0.000 | 1.000 | 0.000 |
| CPT403 | 0.000 | 1.545 | 0.000 |
| CPT501 | 0.000 | 0.000 | 1.000 |
| CPT503 | 0.000 | 0.000 | 1.757 |
| CPT601 | 0.000 | 0.000 | 1.008 |
| CPT603 | 0.000 | 0.000 | 1.621 |

LAMBDA X

|  | KSI 1 |
|---|---|
| MET301 | 3.152 |
| MET302 | 2.830 |

BETA

|  | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 |
| ETA 2 | 0.821 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 1.922 | 0.000 |

GAMMA

|  | KSI 1 |
|---|---|
| ETA 1 | 0.416 |
| ETA 2 | 0.000 |
| ETA 3 | 0.000 |

Table 10 (continued)

PHI

| | KSI 1 |
|---|---|
| KSI 1 | 1.000 |

PSI

| ETA 1 | ETA 2 | ETA 3 |
|---|---|---|
| 4.509 | 7.093 | 0.681 |

THETA EPS

| | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 | MET303 | MET304 | MET306 |
|---|---|---|---|---|---|---|---|---|---|
| CPT401 | 88.694 | | | | | | | | |
| CPT403 | 49.192 | 142.586 | | | | | | | |
| CPT501 | 11.148 | 0.000 | 48.607 | | | | | | |
| CPT503 | 0.000 | 0.000 | 0.000 | 75.110 | | | | | |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 95.150 | | | | |
| CPT603 | 0.000 | 0.000 | -40.003 | -34.854 | 0.000 | 96.416 | | | |
| MET303 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 7.062 | | |
| MET304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 12.987 | |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 5.928 |

THETA DELTA

| MET301 | MET302 |
|---|---|
| 4.637 | 3.639 |

Chi-square with 37 degrees of freedom is 48.93 ($p$ = 0.091).

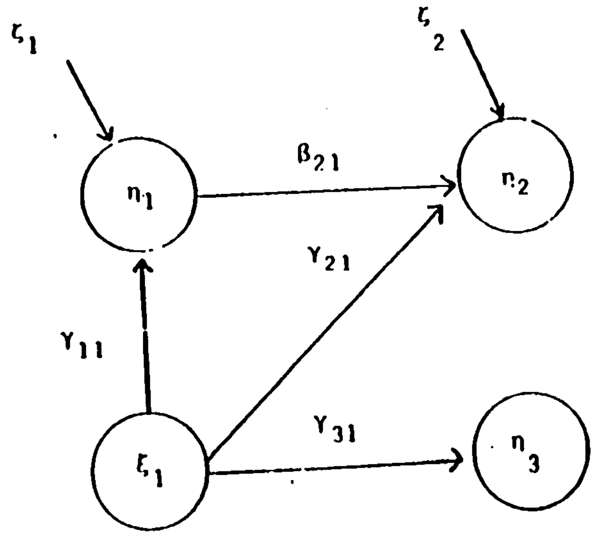
of the parameters not differ, but whether or not they were significant did not change. The interpretation of the model was not affected by the correlated residuals.

The correlated residuals in the model for the No Preschool group are not the same as in the model for the Head Start group. They include both year four observed measures, Reading from years four and five, Word Analysis from years five and six, and Reading in year five and Word Analysis in year six. Without the correlated residuals the model does not fit the observed data ($X^2$=99.47, df=41, $p < 0.001$). However, in the model that includes the correlated residuals, the structural parameters and factor loadings do not change much, but the fit is significantly improved ($X^2$=48.93, df=37, $p$=0.091).

**Model Five: Parent Interview and Years Five and Six**

Model Five differs from those discussed to this point. It is used to examine differences between the Head Start and No Preschool groups in terms of means on the latent variables. It is presented in Figure 15. The maximum likelihood estimates are presented in Table 11. The Head Start and No Preschool samples include 305 and 119 children, respectively. Two latent variables are included, SES and Intermediate Reading Achievement. The expected values for the No Preschool group on the latent variables have been set equal to zero to identify the model. Additionally, the model includes two constants constrained equal to one ( $\xi_1$ and $\eta_3$) to incorporate group differences in the structural and measurement models respectively. (This approach was discussed in detail in Chapter 3.)

A series of three hypotheses was examined. The fit of each model is presented in Table 6. First, the hypothesis of no initial differences in SES ($H_1$: $\gamma_{11}^{(1)} = \gamma_{11}^{(2)} = 0$ ) was tested. (Note that a superscript designates the



$\eta_1$ = SES
$\eta_2$ = **Intermediate Reading Achievement**

Figure 15. Model Five: Parent Interview and Years Five and Six

## Table 11

## Model Five: Parent Interview and Years Five and Six -- No Outcome Differences ($H_5$)

## LISREL Estimates (Maximum Likelihood)

### Head Start Group

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| SES11 | 1.000 | 0.000 | 6.064 |
| SES12 | -1.086 | 0.000 | 10.647 |
| CPT501 | 0.000 | 1.000 | 21.744 |
| CPT503 | 0.000 | 1.762 | 41.031 |
| CPT601 | 0.000 | 1.275 | 28.013 |
| CPT603 | 0.000 | 1.498 | 44.722 |

BETA

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 |
| ETA 2 | -1.948 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.000 | 0.000 |

GAMMA

| | DUMMY |
|---|---|
| ETA 1 | 1.151 |
| ETA 2 | 0.000 |
| ETA 3 | 1.000 |

PHI

| | DUMMY |
|---|---|
| DUMMY | 1.000 |

PSI

| ETA 1 | ETA 2 | ETA 3 |
|---|---|---|
| 1.346 | 24.487 | 0.000 |

THETA EPS

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| SES11 | 3.468 | | | | | |
| SES12 | 0.000 | 6.953 | | | | |
| CPT501 | 0.000 | 0.000 | 35.849 | | | |
| CPT503 | 0.000 | 0.000 | 0.000 | 63.102 | | |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 75.267 | |
| CPT603 | 0.000 | 0.000 | -13.496 | 0.000 | 53.552 | 166.809 |

Table 11 (continued)

Model Five: Parent Interview and Years Five and Six -- No Outcome Differences ($H_5$)

LISREL Estimates (Maximum Likelihood)

No Preschool Group

LAMBDA Y

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| SES11 | 1.000 | 0.000 | 6.064 |
| SES12 | -1.086 | 0.000 | 10.647 |
| CPT501 | 0.000 | 1.000 | 21.744 |
| CPT503 | 0.000 | 1.762 | 41.031 |
| CPT601 | 0.000 | 1.275 | 28.013 |
| CPT603 | 0.000 | 1.498 | 44.722 |

BETA

| | ETA 1 | ETA 2 | ETA 3 |
|---|---|---|---|
| ETA 1 | 0.000 | 0.000 | 0.000 |
| ETA 2 | -1.948 | 0.000 | 0.000 |
| ETA 3 | 0.000 | 0.000 | 0.000 |

GAMMA

| | DUMMY |
|---|---|
| ETA 1 | 0.000 |
| ETA 2 | 0.000 |
| ETA 3 | 1.000 |

PHI

| | DUMMY |
|---|---|
| DUMMY | 1.000 |

PSI

| ETA 1 | ETA 2 | ETA 3 |
|---|---|---|
| 2.193 | 31.732 | 0.000 |

THETA EPS

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| SES11 | 5.623 | | | | | |
| SES12 | 0.000 | 4.374 | | | | |
| CPT501 | 0.000 | 0.000 | 48.631 | | | |
| CPT503 | 0.000 | 0.000 | 0.000 | 85.184 | | |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 63.974 | |
| CPT603 | 0.000 | 0.000 | -30.399 | 0.000 | 0.000 | 77.458 |

Chi-square with 23 degrees of freedom is 33.23 ($p = 0.077$).

group number: group one is Head Start and group two is No Preschool.) The chi-square of this model was compared with that of the model in which $\gamma_{11}^{(1)}$ was not constrained equal to zero ($H_0$). The difference was 24.93 with one degree of freedom ($p < 0.05$); so this hypothesis was rejected.

Similar to the logic of the Analysis of Covariance (ANCOVA), before testing for outcome differences, we tested for parallel slopes of the regression of Intermediate Achievement on SES ($H_2$:$\beta_{21}^{(1)} = \beta_{21}^{(2)}$ ). The chi-square of this model was compared with that of the model of equal factor loadings. The difference is 0.36 with one degree of freedom ($p > 0.05$); so we failed to reject this hypothesis. Consequently, we tested for differences between the two groups in terms of Intermediate Reading Achievement controlling for SES. This was done by testing $H_3$:$\gamma_{21}^{(1)} = \gamma_{21}^{(2)} = 0$. The resulting chi-square was compared with that of $H_2$. The difference is 0.47 with one degree of freedom ($p > 0.05$); so this hypothesis was not rejected. We can conclude that, although the groups differ initially in terms of SES, given a specific level of SES, there is no difference between Head Start and No Preschool in Intermediate Reading Achievement when initial differences are controlled.

The models for the Head Start group include correlated residuals among two pairs of variables: both reading subtests in year six and Reading in year five and Word Analysis in year six. The models for the No Preschool group include only the latter of those. The no outcome differences controlling for initial differences model ($H_3$) does not fit the observed data without the correlated residuals ($X^2$=109.62, df=26, $p < 0.001$). However, by including them the model has a marginally acceptable fit ($X^2$=33.23, df=23, $p$=0.077). With only two exceptions, $\lambda_{52}$ and $\lambda_{62}$, the structural parameters and factor loadings do not change much. However, the signs of these stay the same, and whether or not they are significant does not change. Consequently, the interpretation of the model did not change.

To compare this conclusion with that of ANCOVA, a more popular technique that examines only observed variables, a further analysis was conducted. A multiple regression approach to ANCOVA was used. The dependent variable was the total of the four observed measures of Intermediate Reading Achievement. The two observed measures of SES were covariates. The result of this analysis is that, after accounting for both head of household education and occupation, there is still a significant treatment effect ($t$=-2.671, $p$=0.0078). Dummy coding (0,1) was used, and No Preschool was coded zero. Consequently, the regression coefficient of treatment ($b$=-10.618) indicates a detrimental effect of being enrolled in Head Start. This contradicts the "no effects" (controlling for SES) findings of the analysis using LISREL with structured means. The following chapter includes a discussion of these apparently contradictory findings.

# CHAPTER 6

# DISCUSSION

At the outset, two main objectives were delineated for this study. A model of reading acquisition was to be developed. The model was then to be used to compare treatment groups. To achieve those objectives, a database was obtained from ETS. First, individual item responses were examined. Then test scores were computed and out-of-range values eliminated. After those acceptable scores were determined, the factor structure of the data was examined cross-sectionally. Both pooled and within-group models were tested.

The next stage of analyses involved the longitudinal nature of the data. Initially, it was hoped that all variables from the cross-sectional models could be included when testing the longitudinal models. However, a problem surfaced at this stage. Many subjects were missing one or more test scores. Consequently, procedures for determining which subjects to include and methods of imputing missing data were considered. The patterns of missing data were studied. It was decided that subjects missing no more than one variable per year would be included in further analyses. Moreover, more than one model would be needed to meet the objectives of this study. An examination of the resulting sample sizes revealed that there were five meaningful combinations of variables that could be used. Those combinations of variables constitute the manifest measures of five structural equation models that were tested on the data. Four of those models were tested on the data from two groups, Head Start and No Preschool. The fifth, a model that included all years except year one, was tested only on Head Start data. Because of problems with missing data, none of the longitudinal analyses examined the "Other Preschool" group. Furthermore, the only measures from year one that were included in the analyses came from the parent interview.

Initially, the measurement components of the five structural equation models will be discussed. Next, the causal structures will be discussed. They will be compared and contrasted both across models and groups. Group differences in terms of means on latent variables will then be examined. Finally, the educational implications of the findings will be considered.

## Measurement Models

Each of the five models includes a subset of the total of eight latent variables. In this study of reading acquisition, the two achievement factors, Beginning and Intermediate Reading Achievement, will be discussed first. Beginning Reading Achievement is a general reading ability that encompasses fundamental decoding and comprehension skills that are initially taught in first grade. Of course, the formal introduction of these skills in a school setting does not preclude early mastery by some children, nor does it prevent delayed achievement by others. The observed measures of this factor are the Reading and Word Analysis subtests of the Cooperative Primary Test from Spring of grade one. The corresponding subtests, administered in each of the next two years, measure Intermediate Reading Achievement. At that point in school, a child is expected to develop the skills necessary for independent reading. The reader can better employ the interactive nature of the decoding and comprehension processes. For instance, third graders are generally more capable of using the context to identify an unfamiliar word than are first graders.

The remaining latent variables in the models of reading acquisition parallel the two general approaches to compensatory education that are employed to minimize inadequate preparation for reading instruction. One approach is based on strengthening prerequisite skills. The other, which works less directly, attempts to ameliorate cultural disadvantage. Accordingly, four of the remaining latent variables are pre-reading abilities, and the other two reflect home background.

Several standardized tests are available to assess a child's "readiness" to begin reading instruction. Five subtests of one of the more popular batteries, the Metropolitan Readiness Test, are the observed measures of two factors, Verbal and Visual Readiness. Word Meaning and Listening are used to measure the former; Copying, Alphabet, and Matching measure the latter. This battery was administered at the end of kindergarten.

Although readiness measures are generally administered in late kindergarten or early in grade one, some of the models incorporate two pre-readiness abilities (Verbal and Perceptual Discrimination) which were assessed in the spring prior to kindergarten. The Cooperative Preschool Test (also known as the Caldwell) and ETS Matched Pictures Task are each indicators of Verbal Ability. Two subtests of the Johns Hopkins Perceptual Test (Perception and Analysis) are the observed measures of Perceptual Discrimination.

Socioeconomic Status (SES) and Educational Future are the home background factors. Each has two observed measures, all of which come from the parent interview. Occupation and education of the head of household are the indicators of SES, while the measures of Educational Future are parental aspirations, and expectations about the number of years their child will attend school.

The lower bound reliability estimates of each observed variable are presented in Table 12. These estimates represent the proportion of variance in a

## Table 12
## Lower Bound Reliability Estimates of Observed Variables

| | Model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | | 3 | | 4 | | 5 | |
| | Group | | | | | | | | |
| | HS | HS | NP | HS | NP | HS | NP | HS | NP |
| Variable | | | | | | | | | |
| SES3 | .252 | .260 | .135 | .512 | .031 | | | | |
| SES4 | .373 | .363 | .744 | .610 | .384 | | | | |
| SES11 | .180 | .127 | .640 | .106 | .449 | | | .423 | .311 |
| SES12 | .494 | .562 | .548 | .591 | .487 | | | .301 | .406 |
| CLD201 | .807 | .851 | .613 | | | | | | |
| PIC209 | .521 | .468 | .410 | | | | | | |
| JHP201 | .571 | .625 | .999 | | | | | | |
| JHP202 | .306 | .354 | .173 | | | | | | |
| MET301 | .501 | .418 | .757 | .218 | .583 | .535 | .682 | | |
| MET302 | .527 | .519 | .851 | .295 | * | .611 | .688 | | |
| MET303 | .428 | .476 | .514 | .507 | .703 | .410 | .480 | | |
| MET304 | .415 | .511 | .459 | .469 | .366 | .473 | .519 | | |
| MET306 | .404 | .395 | .508 | .455 | .380 | .329 | .329 | | |
| CPT401 | .087 | | | .317 | .550 | .122 | .127 | | |
| CPT403 | .377 | | | * | .915 | .355 | .161 | | |
| CPT501 | .483 | | | .533 | .471 | .502 | .426 | | |
| CPT503 | .710 | | | | | .600 | .639 | .640 | .568 |
| CPT601 | .360 | | | | | .397 | .315 | .439 | .479 |
| CPT603 | .259 | | | | | .332 | .537 | .327 | .512 |

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* Note. Reliability cannot be computed because residual variance was not estimated.

manifest variable that is explained by the latent constructs. It is computed by subtracting the ratio of residual variance to observed variance from one. (That is, $R_{ii} = 1.0 - \Theta_{ii}/S_{ii}$ .) The estimates differ both across models and groups. The reason for this disparity is unclear.

The subtests of the Cooperative Primary Test that were administered in year five are the most reliable (about 0.50 to 0.70). The year four and six administrations of that instrument are generally less reliable (0.10 to 0.92). The Metropolitan Readiness subtests are fairly reliable, generally ranging from 0.40 to 0.70. The observed measures of the pre-readiness factors vary, but for the most part are quite reliable (0.17 to 0.85). Two of the parent interview items, educational expectations and education of head of household, are very reliable (about 0.30 to 0.60). This is higher than expected from individual items. The other two parent interview items have weaker reliabilities, generally ranging from 0.10 to 0.40. This is not unexpected: they are individual items from an interview and likely to be more fallible than subtests, which are comprised of several items.

The reliabilities indicate the fallibility of observed measures. The correlation among any pair of those variables is attenuated due to measurement error. Borhnstedt and Carter (1971) clearly demonstrate that in multiple regression, when measurement error is present in an independent variable, the estimate of a regression coefficient is biased. The direction of that bias is inconsistent. That is, the estimate can be attenuated, inflated, or even have the wrong sign. For that reason, the results of an analysis that includes a fallible independent variable can lead to erroneous conclusions. Unreliability is not a problem with latent variables. Consequently, the relationships among factors are stronger than those among corresponding observed variables and the structural parameter estimates are less likely to be biased.

### Structural Models

The causal relationships among the latent variables that were just described will now be considered. Deciphering patterns of causality from these models is difficult because the models include a variety of combinations of latent variables. For instance, one model includes home-background, pre-readiness, readiness, and achievement factors (Model One). One model includes home background, readiness, and achievement factors (Model Three). One model includes only home background and achievement factors (Model Five). One model includes only readiness and achievement factors (Model Four). Finally, one includes home background, pre-readiness and readiness, but not achievement factors (Model Two).

For that reason, the following discussion of causality in the models will distinguish between cross-sectional and longitudinal effects. The cross-sectional examination considers effects within five categories of latent variables: home background, pre-readiness, readiness, beginning achievement, and intermediate achievement. The longitudinal effects include direct influences among those categories. First, the three cross-sectional effects will be presented.

### Cross-sectional Effects

There is an effect of SES on Educational Future in models for the Head Start group only. This is exhibited in Models One, Two, and Three. That is, SES influences parental beliefs about their child's educational future. This effect does not exist in the models for the No Preschool group.

Each model that incorporates the pre-readiness period includes the second cross-sectional effect, the influence of Verbal Ability on Perceptual

Discrimination. Because the more general Verbal Ability subsumes a specific ability to follow directions, it affects ability to perform on perceptual tasks that are directed verbally. This effect exists in models for both groups.

The third cross-sectional effect involves latent readiness variables. These are included in Models One through Four. In each model Verbal Readiness influences Visual Readiness. The explanation for this parallels that of the within pre-readiness effect. Facility with verbal communication influences performance on an orally directed task requiring non-verbal output. Again, this effect is consistent across groups.

### Longitudinal Effects

There are six types of longitudinal effects among the latent variables. First, there is an influence of home background on pre-readiness. The effect can be examined in both models that include these two categories of latent variables (Models One and Two). However, they differ across groups. In the models for the Head Start group, SES influences both latent pre-readiness variables. That influence is mediated by Educational Future in Model One and by both Educational Future and Verbal Ability in Model Two. There is also a direct influence of SES on Perceptual Discrimination in Model Two. In contrast, the only effects of home background on pre-readiness ability in any model for the No Preschool group are those from SES to Verbal Ability and the subsequent Verbal influence on Perceptual Discrimination in Model Two.

Why does such a difference exist between the two groups? The parents who chose to enroll their children in Head Start differ from the others. A child's enrollment in Head Start is evidence of this difference. Furthermore, Model Five demonstrates that the Head Start parents are lower-level SES. (This will be discussed in detail below.) The mediated effect of Educational Future on pre-readiness ability is another difference between the home backgrounds of Head Start and No Preschool children. Needless to say, the parents' background cannot be altered. Fortunately, this does not destine the child to limited educational success. A home where a supportive attitude toward education exists may in fact be a home which nurtures a drive for education. That support could explain the enrollment of those children in the Head Start programs.

The second type of longitudinal effect is another influence of the home this time on readiness. It is found in Model Three of the Head Start group. Educational Future, which itself is influenced by SES, directly affects Verbal Readiness. This effect is not significant in the corresponding model for the No Preschool group.

The third type of longitudinal effect is that of pre-readiness ability on readiness. Both Models One and Two (the only models which incorporate both pre-readiness and readiness factors) include this effect. In the models for the Head Start group pre-readiness Verbal Ability affects Visual Readiness both directly and indirectly through Verbal Readiness. In the No Preschool model, only the direct influence exists. In no model is there an influence of the pre-readiness factor, Perceptual Discrimination, on readiness or achievement. This is contrary to what one would expect. Perceptual discrimination is undoubtedly employed when a child attempts to differentiate between two letters by detecting distinctive features (e.g., Gibson, 1965; Gibson & Levin, 1975). Perceptual skills are often measured in readiness batteries. However, the measures of Perceptual Discrimination included in this study were administered in the spring prior to kindergarten. That is at least one year earlier than readiness is typically assessed. Had Perceptual Discrimination been measured one year later, its effect on achievement may have been significant.

The fourth type of longitudinal effect that exists in the models is the influence of readiness on achievement. This effect has been proposed since the term "reading readiness" was first used by the National Committee on Reading in 1925 (Coltheart, 1979; Anderson, Hiebert, Scott, & Wilkinson 1985). Component skills advocates (e.g., Deputy, 1930; Gates, 1939) claimed an effect of readiness on achievement. It was the belief in this effect which encouraged the development of reading readiness curricula. The models developed in this study support that claim: mastery of prerequisite skills facilitates reading achievement.

The effect of readiness on achievement exists in Models One, Three and Four. The specific effects are less consistent across models than those presented above. The effect of Verbal Readiness on Early Reading Achievement is mediated by Visual Readiness in Models One (for the Head Start group) and Four (for the No Preschool group). It is both direct and mediated in Model Three (for the No Preschool group) and Model Four (for the Head Start group). There is no significant effect of readiness on Reading Achievement in Model Three for the Head Start group.

The fifth longitudinal effect will now be discussed. The influence of readiness on Intermediate Achievement is always mediated by Early Achievement In other words, the models allow for the long-term effects of readiness deficits to be offset by effective reading instruction in grade one. It is not clear from these models whether such instruction must directly address those deficits. It is possible that some children overcome these deficits during beginning reading instruction (even though they did not do so during readiness instruction). The final type of longitudinal effect, home background on achievement, will be considered below in the discussion of group differences.

One way of evaluating the combined strength of causal relationships is to examine the proportion of variance in each latent endogenous variable that is accounted for in each model. Although squared multiple correlation coefficients are presented for all endogenous factors in Table 13, only those of reading achievement will be discussed here. This is because it is the acquisition of reading that we have attempted to explain in the models. Models One, Three, and Four include both readiness and achievement constructs. Approximately seventy to eighty percent of the variance in Beginning and Intermediate Reading Achievement is accounted for in the models for the Head Start group. The models for the No Preschool group are less consistent. Over ninety percent of the variance in Intermediate Reading Achievement is explained in Model Four. However, only twenty-five to forty percent is accounted for in the other achievement factors both in that model and in Model Three. There is no obvious explanation for these differences.

Group Differences: Structured Means

Initial and outcome differences between the Head Start and No Preschool groups were examined in Model Five. The two groups were compared in terms of means on latent home background and achievement variables. Initial SES differences were accounted for in the model. Then, controlling for those differences, the groups were compared in terms of Intermediate Reading Achievement. (Note that a statistical adjustment, and not actual control through matching of subjects, was used to control for initial differences.)

SES, a latent variable with two manifest variables, head of household education and occupation, is significantly different across the two groups. More specifically, the children who were not enrolled in preschool are from homes of higher SES than those enrolled in Head Start. Similar to the logic of ANCOVA,

## Table 13
## Squared Multiple Correlations

| | Model | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | | 3 | | 4 | | 5 | |
| | Group | | | | | | | | |
| | HS | HS | NP | HS | NP | HS | NP | HS | NP |
| Latent Variable | | | | | | | | | |
| Educational Future | .728 | .487 | .338 | .290 | .682 | | | | |
| Verbal Ability | .496 | .489 | .253 | | | | | | |
| Perceptual Discrimination | | .776 | .676 | .246 | | | | | |
| Verbal Readiness | .261 | .287 | .036 | .237 | .045 | | | | |
| Visual Readiness | .581 | .594 | .879 | .913 | .254 | .454 | .308 | | |
| Beginning Achievement | .703 | | | .853 | .246 | .837 | .382 | | |
| Intermediate Achievement | .853 | | | | | .769 | .984 | .295 | .199 |

Intermediate Reading Achievement levels of the groups was compared after accounting for SES. It was determined that, given a value of SES, there is no achievement difference between the groups. Although Head Start children had lower SES and Intermediate Reading Achievement means, for a given level of SES, the latent achievement ability was not significantly different.

To contrast these findings with those in which observed variables are used, an ANCOVA was performed. Contrary to the analysis with structured means, the No Preschool group had significantly higher reading achievement scores when SES was controlled. In other words, Head Start was apparently detrimental, if one believes this analysis.

This finding concurs with that demonstrated by Campbell and Erlebacher (1970). They showed that, because of regression artifacts and fallible covariates, an ANCOVA can understate positive effects and overstate negative effects of programs that are designed to serve the disadvantaged. As mentioned above, Borhnstedt and Carter (1971) demonstrate that, in multiple regression, measurement error can result in a biased estimate of a regression coefficient. Detrimental effects of treatment might be estimated when, in fact, beneficial effects occurred, or vice-versa. Consequently, the results of a regression analysis involving fallible independent variables can lead to erroneous conclusions. This caveat applies to ANCOVA, a special case of multiple regression, in which the covariate is considered prior to the independent variables.

However, when using latent variables, measurement error is not a problem. That is, neither the covariate nor the outcome variable are fallible measures. Consequently, the results from an analysis that uses latent variables to examine treatment effects, controlling for pre-treatment differences, are more likely to be accurate. Furthermore, correlations among latent variables are not attenuated due to measurement error. Consequently, Model Five resulted in explanation of over twice the variance as in the ANCOVA. Specifically, the squared multiple correlation coefficient in the ANCOVA was 0.092, whereas in the model with structured means it was 0.295 for the Head Start group and 0.199 for the No Preschool group.

Specification error, however, can be a potential source of bias in both multiple regression and structural equation models. It exists when variables are incorrectly excluded from a model, or when effects are incorrectly specified as causes, or causes specified as effects (Deegan, 1974). In a model that is misspecified, parameter estimates can be overestimated, underestimated, or have the wrong sign. Significance testing of the structural parameters may lead to inaccurate conclusions. Borhnstedt and Carter (1971) state, "... if we hypothesize the wrong model, then our estimation of that model will yield meaningless estimates" (p. 141). For that reason, we attempted to include all relevant variables in the models that were hypothesized in this study. However, some variables could not be included in the models either because they were not available for many of the subjects or because they were not available in the data set at all.

In this study, cross-sectional factor analyses were conducted prior to the testing of structural equation models. The factor models formed the basis for the measurement components of the final structural equation models. This is an acceptable strategy in model fitting. However, it introduces the possibility of omitting observed variables (during the factor analyses) that otherwise might be included in the causal models. For instance, measures of auditory discrimination, auditory-visual integration, and visual discrimination were originally selected from the ETS data base because they were expected to influence reading achievement. However, many of them were eliminated when the factor analyses were conducted. Consequently, those variables were not included in the final models of reading acquisition. By employing the strategy of preceding structural equation modelling with factor analyses, the likelihood of specification error might be increased.

In addition to specification error, structural equation models have other potential problems. Four of those will be discussed. First, it is assumed that the relationships among the variables in the models are linear. Second, it is assumed that there are no interactions among the observed variables. These two assumptions reflect both mathematical limitations of the modelling procedure and a need for an understanding of the content area. The next assumption, that of univariate normality of observed variables, can be verified by examining the skewness and kurtosis of each distribution. The variables examined in this study were each found to have small skewness and kurtosis. The fourth assumption, multivariate normality is generally difficult to check. In practice, we check for univariate normality. The assumptions of an ANCOVA are not as strict. However, in this study it was shown that the results can differ from those of LISREL. Consequently, the tradeoff of added assumptions of LISREL versus relative simplicity of ANCOVA appears to be worthwhile.

## Educational Implications

Two general approaches that are used to minimize early reading failures were considered in this study. One approach is designed to serve those considered at risk based on SES. The other attempts to identify and augment skills deficits. The impact of Head Start, a program designed to reduce the effect of cultural disadvantage, was evaluated by comparing the reading achievement of children enrolled in the program with those who did not attend preschool. The skills deficit question was addressed less directly. That is, a comparison was not made between those enrolled in a remediation program with those not enrolled. Instead, the influence of readiness on achievement was studied. The strategy employed was not one of program evaluation, but one of psychometrics. The reliability and construct validity of observed measures and predictive values of latent variables were examined.

At the outset, it was hoped that these two approaches would be amalgamated. However, because of the nature of the data the amalgamation never evolved. A close examination of the data revealed that there were no pre-treatment measures of readiness available to include in the longitudinal models. Consequently, in the models that compared groups in terms of initial differences, we controlled for SES. Despite that shortcoming in the achievement of the original objectives, several models of reading acquisition were developed that fit the data.

The educational implications of the findings of this study will be presented in two parts. First, the models of reading acquisition will be considered. Then, the impact of Head Start will be discussed. A model of reading acquisition was to be developed in this study. In fact, because of the nature of the data, five models were developed that fit the observed data. Several issues were addressed in the building and interpretation of those models. First, in an attempt to account for individual differences in reading achievement, readiness and achievement constructs were identified. Then causal relationships among those constructs were examined.

Readiness batteries are usually administered to children in late kindergarten or early grade one. The results of that testing are used to determine ability and often used to match methods and materials with individual needs. Assessment assumes an understanding of the relationship between readiness and achievement. Although this study did not develop a definitive recipe for readiness assessment, the modelling procedures address related questions. For instance, the models include two dimensions of readiness. Both are measured by the Metropolitan Readiness Tests.

The models which incorporate pre-reading abilities confirm that which has been shown in the literature: there are underlying skills prerequisite to reading. The models do not include any direct effects on achievement that are not already assessed in many schools. Consequently, the results do not suggest the assessment of new pre-reading abilities. (Of course, the constructs examined in the analyses were limited by the instruments selected by the original researchers.) The results demonstrate the value of some that are currently assessed in the schools. The reliabilities of the readiness measures were generally respectable.

The findings of the models support the assessment of readiness. At present, many schools routinely administer readiness tests. However, some do not. For instance, the New York City Board of Education does not mandate board-wide readiness testing. A few of the districts have chosen to do so. However, that affects only a small percentage of the children who enter first grade in New York City public schools. Teachers and others who influence school policy should be aware of the importance of readiness assessment. The models in this study demonstrate the predictive validity of readiness tests. They serve a valuable purpose: accounting for individual differences in reading achievement. The results of reading readiness tests should be used, as they are in many schools, to identify children who are at risk. Those children could then be placed in compensatory education programs designed to strengthen pre-reading skills. This strategy could reduce the number of children who are inadequately prepared for, and consequently fail in, their initial encounter with formal reading instruction.

It would be of interest to conduct future analyses that include additional standardized readiness and achievement measures. One could compare the factor structures of the Metropolitan Readiness Test with those of other popular tests such as the Clymer Barrett Pre-Reading Battery or the Murphy-Durrell Readiness Test. Similar comparisons could be made across achievement batteries. Then the causal relationships among the readiness and achievement constructs could be compared.

The models in this study are longitudinal. Causal relationships among constructs are examined. However, the interplay among concurrent processes is not considered. Relative to an interactive model of reading, the constructs in these models are not appropriate for the examination of reading as a dynamic process. Reading rates and capacity are not among the constructs incorporated in the models. The interactive framework emphasizes the dependence of comprehension on decoding. In the models in this study decoding and comprehension are each observed measures of the same ability. Had several measures of each been available, and separate constructs been extracted, the causal relationships between lexical access and comprehension could have been studied. The variables that were selected from the ETS database did not allow for such an exploration. An investigation of that type would require several measures designed to assess verbal efficiency: the outcome quality relative to the processing costs (Perfetti, 1985). That was not the intention of this study.

The impact of Head Start on reading achievement was examined. None of the other goals of Head Start was evaluated. It must be emphasized that the findings of this study are limited to those groups included in the study. Inferences regarding Head Start, in general, must not be drawn from this study. The groups were comprised of select subjects, those meeting the "maximum missings" criteria. One cannot assume that those subjects are representative samples of their treatment groups.

By examining latent variables, the analyses avoided the pitfalls of the controversial Westinghouse/Ohio University evaluation of Head Start (Cicarelli, Cooper and Granger, 1969). LISREL with structured means is likely to be a more accurate method of assessing the treatment effect than ANCOVA. The Westinghouse/Ohio University study was criticized on methodological grounds (e.g., Campbell and Erlebacher, 1970). Magidson (1977), Bentler and Woodward (1978 and 1979), and Magidson and Sörbom (1982) successively built on prior critiques and examined the impact of Head Start on readiness. The technique used to examine group differences in this study, is the same as that of Magidson and Sörbom. However, we examined a longer-term impact of Head Start. The reading achievement of Head Start participants at a given level of SES, three to four years after they completed the program, was not significantly different from those who did not attend preschool. Although this is not a positive finding, Head Start was not estimated to have a detrimental effect, a result reported in previous research (e.g., aspects of the Westinghouse/Ohio University evaluation). The reasons for the no effects findings are unclear. As mentioned above, by design of Head Start, the curricula vary across sites. None of the available documentation from the ETS Longitudinal Study describes the individual Head Start programs well enough to determine why it did not have an effect.

## Appendix A

Instruments selected from the ETS-Head Start Longitudinal Study[1]

Hess & Shipman Toy Sorting Task (1)
Hess & Shipman Eight-block Sorting Task (1,2,3)
ETS Matched Picture Language Comprehension Task (1,2,3)
Cooperative Preschool Inventory -- Caldwell (1,2,3)
Form Reproduction (1,2,3)
WPPSI Picture Completion Subtest (1,3)
WISC Picture Completion Subtest (4,6)
Sigel Object Categorizing Test (1,2,3,4,6)
Massad Mimicry Test (1,2,3,4)
TAMA General Knowledge Test (1,2)
Johns Hopkins Perceptual Test (1,2)
ETS Story Sequence Task (1,2,3,6)
Matching Familiar Figures Test (1,2,3,4,6)
Fixation Time (1,2)
Children's Auditory Discrimination Inventory (1,2)
Peabody Picture Vocabulary Form A -- Receptive (1,2)
Peabody Picture Vocabulary Form B -- Productive (1,2)
WPPSI Block Design Subtest (3,4)
WISC Block Design Subtest (6)
Wepman Auditory Discrimination Inventory (3,4)
Metropolitan Readiness Test (3)
ETS Test of Linguistic Structures (4)
Auditory Visual Integration Test (4,6)
Bender Gestalt (4,6)
Human Figure Drawing Test (4,6)
Cooperative Primary Tests (4,5,6)
Thurstone Spatial Relations (6)
Ravens Progressive Matrices (4,6)
Parent Interview (1)
Personal Data: sex, race, preschool & site

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[1] The years that each instrument was administered are indicated in parentheses.

## Appendix B

### Description of Instruments used in the Confirmatory Analyses

### Cooperative Preschool Test (Caldwell) [1]

The Cooperative Preschool Inventory was developed to be used with disadvantaged children as a measure of school readiness . It was normed on Head Start Children. It purportedly taps verbal, quantitative and perceptual-motor skills. The 1970 Revised Edition of this individually administered instrument was used. Items generally fit into one of four major categories:

1) Personal-social responsiveness (e.g., "How old are you?").

2) Associative vocabulary (e.g., "What does a dentist do?").

3) Concept activation: numerical (e.g., "How many wheels does a car have?").

4) Concept activation: sensory (e.g., "Which is heavier a brick or a shoe?").

### Cooperative Primary Tests [2]

Each subtest is administered in a group setting. The child is instructed to select, from a row of pictures, that which goes best with a stimulus. Three subtests were examined in this study: Reading, Listening and Word Analysis.

1) **Listening** is a test of comprehension, recall and interpretation of the spoken word. e.g., "Which picture goes best with this. **I went for a ride.** Make a big X on the picture that goes best with **I went for a ride.**

2) **Word Analysis** "is a test of understanding of structural and phonetic properties of words".

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[1] Note. Adapted from Shipman, V.C. (1972). Disadvantaged children and their first school experiences: ETS-Head Start Longitudinal Study. (ETS Document PR-72-27). Princeton, N.J.: Educational Testing Service.

[2] Note. Adapted from ETS (1967). Handbook: Cooperative Primary Tests. Princeton, N.J.: Cooperative Tests and Services.

e.g., a) What rhymes with **knee**? Make a big X on the one that rhymes with **knee**.
b) What has the same sound in it as **man**?

3) **Reading** "is a test of ability to read words, sentences, paragraphs and long passages with understanding". (This was designed to have a structure that is parallel to that of Listening.)

e.g., Read the sentence in the arrow. Then make a big X on the box that goes best with it. **Ann's basket has a ribbon on it but no eggs in it.**

ETS Matched Pictures Language Comprehension Task [3]

This test was constructed for use in the ETS Longitudinal Study to examine linguistic competence. The instrument assesses a variety of grammatical categories such as: past, present and future tenses, negation and coordinate comparatives. The examiner shows the child a pair of pictures and tells him what the pictures are called. The child is asked to point to the picture that is named. For example, the child may be presented with picture names such as "The cat is drinking" and "The cat will drink". One of those names is then identified as the stimuli and the child is to select the corresponding picture.

ETS Story Sequence I and II [4]

The ETS Story Sequence, an instrument developed for the ETS-Head Start Longitudinal Study, is used to assess a child's understanding of sentences, short sequences and sequence relationships. The child is presented either three or four cards containing cartoon-like pictures. The two subtests retained for the present research are measures of productive language ability.

1) **Productive language verbal recall.** The tester tells a story and presents the cards in order. The child is to retell the story.

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[3] Note. Adapted from Shipman, V.C. (1972). Disadvantaged children and their first school experiences: ETS-Head Start Longitudinal Study. (ETS Document PR-72-27). Princeton, N.J.: Educational Testing Service.

[4] Note. Adapted from Shipman, V.C. (1972). Disadvantaged children and their first school experiences: ETS-Head Start Longitudinal Study. (ETS Document PR-72-27). Princeton, N.J.: Educational Testing Service.

2) **Productive language using child's story telling.** The child tells a story using the cards that are presented in an array.

Johns Hopkins Perceptual Test[5]

The Johns Hopkins Perceptual Test was developed as a diagnostic instrument for children with "functional or organically determined speech defects, limited verbal and experiential repertoires, or motor handicaps, as well as very young or retarded children". This instrument was included in the ETS Longitudinal Study as a measure of perception. It is an individually administered battery. There are two subtests. The first of these, Form Perception, is used to assess a child's ability with global comparison. The other, Analysis, involves the perception of more complex figures. The tasks require that a child choose a form that is identical to a stimulus. The stimuli are each black geometric figures on white cards.

Metropolitan Readiness Tests [6]

The Metropolitan Readiness Tests were developed to assess "the extent to which school beginners have developed the several skills and abilities that contribute to readiness for first-grade instruction". Five subtests of this battery were included in the pilot study: Word Meaning, Listening, Matching, Alphabet. and Copying.

1) **Word Meaning** was designed to measure a child's vocabulary. For example: "Look at the first row of pictures. Mark the windmill."

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[5]. Note. Adapted from Shipman, V.C. (1972). Disadvantaged children and their first school experiences: ETS-Head Start Longitudinal Study. (ETS Document PR-72-27). Princeton, N.J.: Educational Testing Service.

[6]. Note. Adapted from Hildreth, G.H., Griffiths, N.L. & McGauvran, M.E. (1969). Metropolitan Readiness Tests: Manual of Directions (Forms A and B). New York: Harcourt, Brace and World, Inc.

2) **Listening** purportedly "taps the child's knowledge of the world about him and his ability to comprehend sentences and paragraphs". For example: "In Switzerland the cows wear bells around their necks so the boy can find them when they wander away. Mark the picture that shows this."

3) **Matching** was developed to assess a child's visual-perceptual skills. For example: Look at the picture of the sailboat at the edge of the page -- by itself, before the green line. Find another picture in the same row that is just like it and make a mark in that one."

4) **Alphabet** was designed to measure a child's familiarity with the names of the letters of the alphabet. For example: "Now, in the box where the cup is, mark the e".

5) **Copying** is described as a "test in which the child manifests a combination of visual perception and motor control". For example: "In the first row of boxes at the top of the page, find the box with a circle in it. Take your pencil and in the same box draw another circle just like the one that is already there."

### Parent Interview[7]

The Parent Interview variables came from an extensive interview that was conducted by Audits and Surveys, Inc. in Spring, 1969. The interview consisted of several hundred questions. Because a subset of approximately thirty background items from this interview was already created by ETS it was obtained for this study. The decision as to which of these items to include in the initial factor analyses was based on beliefs regarding home influence on reading achievement. The five items which fit together well in the confirmatory factor analyses will now be presented as they appeared in the interview.

1) **Educational aspirations.** "If you could have your wish, what grade would y... like (SAMPLE CHILD) to complete?"

2) **Educational expectations.** "Since things don't always turn out the way we want them to, how far do you think (SAMPLE CHILD) will actually go in school?"

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[7] Note. Adapted from Audits and Surveys, Inc. (1969). Young children and their first school experiences: Parent Interview (Project No. 5370). New York: Author.

3) **Reading to child.** "Do you ever read or tell children's stories to (SAMPLE CHILD)?"

0) If no.

If yes: "About how often?"
1) Once in awhile (less than once a week).
2) About once a week.
3) Several times a week.
4) Regularly (at least once a day).
5) Very frequently (much of each day).
6) Don't know. (This response was treated as missing data.)

4) **Occupational level of head of household.** The first digit of Duncan's Occupational Codes was used. The range was from 0 to 9 (i.e., professional to laborer), and 10 was unemployed.

5) **Educational level of head of household.** The last grade completed was recorded.

Peabody Picture Vocabulary Test [8]

The Peabody Picture Vocabulary Test, an individually administered battery, was designed to provide an estimate of the subject's "verbal intelligence". Two forms of the test were administered. Form A is used to assess a child's receptive language ability. The tester reads a word aloud and the child is to point to that picture, among four choices, that corresponds to the word. Form B was modified by the staff at ETS to measure a child's productive language ability. In this test, the examiner points to a picture and the child is to respond by saying what is in the picture. Each of the forms includes two subtests: nouns and verbs. Examples of stimuli include: **car, building** and **submarine.**

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[8]. Note. Adapted from Dunn, L.M. (1965). Peabody Picture Vocabulary Test Manual. Circle Pines, MN: American Guidance Service.

## Appendix C.1

## Confirmatory Factor Analysis Cross-Sectional Models of Best Fit -- Pooled Data

## Parent Interview

### Covariance Matrix Analyzed

| | SES3 | SES4 | SES8 | SES11 | SES12 |
|---|---|---|---|---|---|
| SES3 | 5.390 | | | | |
| SES4 | 3.099 | 5.144 | | | |
| SES8 | 0.634 | 0.769 | 1.928 | | |
| SES11 | -2.242 | -3.081 | -1.131 | 9.860 | |
| SES12 | 3.254 | 4.061 | 1.566 | -6.660 | 12.799 |

### LISREL Estimates (Maximum Likelihood)

LAMBDA X

| | KSI 1 | KSI 2 |
|---|---|---|
| SES3 | 1.556 | 0.000 |
| SES4 | 1.992 | 0.000 |
| SES8 | 0.000 | 0.527 |
| SES11 | 0.000 | -2.222 |
| SES12 | 0.000 | 2.987 |

PHI

| | KSI 1 | KSI 2 |
|---|---|---|
| KSI 1 | 1.000 | |
| KSI 2 | 0.689 | 1.000 |

THETA DELTA

| | SES3 | SES4 | SES8 | SES11 | SES12 |
|---|---|---|---|---|---|
| SES3 | 2.970 | | | | |
| SES4 | 0.000 | 1.177 | | | |
| SES8 | 0.000 | 0.000 | 1.651 | | |
| SES11 | 0.000 | 0.000 | 0.000 | 4.921 | |
| SES12 | 0.000 | 0.000 | 0.000 | 0.000 | 3.879 |

Chi-square with 4 degrees of freedom is 3.77 (p = 0.438).

## Appendix C.2

## Year One

### Covariance Matrix Analyzed

| | JHP101 | JHP102 | PBA102 | PBA103 | PBB102 | PBB103 |
|---|---|---|---|---|---|---|
| JHP101 | 8.281 | | | | | |
| JHP102 | 3.032 | 5.577 | | | | |
| PBA102 | 3.004 | 0.979 | 9.411 | | | |
| PBA103 | 10.625 | 3.107 | 27.110 | 104.815 | | |
| PBB102 | 1.591 | 0.648 | 4.062 | 14.779 | 6.711 | |
| PBB103 | 4.773 | 1.022 | 11.455 | 41.839 | 10.708 | 34.888 |

### LISREL Estimates (Maximum Likelihood)

LAMBDA X

| | KSI 1 | KSI 2 |
|---|---|---|
| JHP101 | 1.079 | 0.000 |
| JHP102 | 0.320 | 0.000 |
| PBA102 | 2.732 | 0.000 |
| PBA103 | 9.922 | 0.000 |
| PBB102 | 0.000 | 1.945 |
| PBB103 | 0.000 | 5.506 |

PHI

| | KSI 1 | KSI 2 |
|---|---|---|
| KSI 1 | 1.000 | |
| KSI 2 | 0.765 | 1.000 |

THETA DELTA

| | JHP101 | JHP102 | PBA102 | PBA103 | PBB102 | PBB103 |
|---|---|---|---|---|---|---|
| JHP101 | 7.116 | | | | | |
| JHP102 | 2.687 | 5.475 | | | | |
| PBA102 | 0.000 | 0.000 | 1.948 | | | |
| PBA103 | 0.000 | 0.000 | 0.000 | 6.363 | | |
| PBB102 | 0.000 | 0.000 | 0.000 | 0.000 | 2.929 | |
| PBB103 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4.577 |

Chi-square with 7 degrees of freedom is 4.94 (P = 0.667).

## Appendix C.3

## Year Two

```
                  Covariance Matrix Analyzed

       CLD201     PIC209     JHP201     JHP202
CLD201     156.941
PIC209      27.588     10.832
JHP201      19.169      4.021      6.881
JHP202      13.857      2.548      3.082      7.277

           LISREL Estimates (Maximum Likelihood)

                        LAMBDA X

                     KSI 1      KSI 2
           CLD201   11.615      0.000
           PIC209    2.375      0.000
           JHP201    0.000      2.085
           JHP202    0.000      1.478

                          PHI

                   KSI 1      KSI 2
           KSI 1   1.000
           KSI 2   0.795      1.000

                      THETA DELTA

           CLD201     PIC209     JHP201     JHP202
CLD201     22.030
PIC209      0.000      5.190
JHP201      0.000      0.000      2.535
JHP202      0.000      0.000      0.000      5.091

Chi-square with 1 degrees of freedom is 3.71 (p = 0.054).
```

## Appendix C.4

## Year Three

### Covariance Matrix Analyzed

| | MET301 | MET302 | MET303 | MET304 | MET306 | STY302 | STY304 |
|---|---|---|---|---|---|---|---|
| MET301 | 12.596 | | | | | | |
| MET302 | 6.362 | 10.500 | | | | | |
| MET303 | 3.992 | 4.320 | 12.475 | | | | |
| MET304 | 6.154 | 6.147 | 9.428 | 26.490 | | | |
| MET306 | 2.334 | 2.314 | 4.804 | 6.600 | 8.804 | | |
| STY302 | 1.001 | 1.106 | 1.584 | 2.748 | 0.918 | 3.338 | |
| STY304 | 2.899 | 2.681 | 3.232 | 5.535 | 2.601 | 3.198 | 9.476 |

### LISREL Estimates (Maximum Likelihood)

### LAMBDA X

| | KSI 1 | KSI 2 | KSI 3 |
|---|---|---|---|
| MET301 | 0.000 | 0.000 | 2.504 |
| MET302 | 0.000 | 0.000 | 2.541 |
| MET303 | 2.562 | 0.000 | 0.000 |
| MET304 | 3.771 | 0.000 | 0.000 |
| MET306 | 1.767 | 0.000 | 0.000 |
| STY302 | 0.000 | 1.191 | 0.000 |
| STY304 | 0.000 | 2.684 | 0.000 |

### PHI

| | KSI 1 | KSI 2 | KSI 3 |
|---|---|---|---|
| KSI 1 | 1.000 | | |
| KSI 2 | 0.521 | 1.000 | |
| KSI 3 | 0.622 | 0.398 | 1.000 |

Appendix C.4 (continued)

THETA DELTA

|  | MET301 | MET302 | MET303 | MET304 | MET306 | STY302 | STY304 |
|---|---|---|---|---|---|---|---|
| MET301 | 6.328 |  |  |  |  |  |  |
| MET302 | 0.000 | 4.042 |  |  |  |  |  |
| MET303 | 0.000 | 0.000 | 5.909 |  |  |  |  |
| MET304 | 0.000 | 0.000 | 0.000 | 12.270 |  |  |  |
| MET306 | 0.000 | 0.000 | 0.000 | 0.000 | 5.682 |  |  |
| STY302 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.919 |  |
| STY304 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 2.270 |

Chi-square with 11 degrees of freedom is 16.82 (p = 0.113).

## Appendix C.5

### Years Four, Five, and Six

Covariance Matrix Analyzed

| | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| CPT401 | 113.468 | | | | | |
| CPT403 | 88.907 | 174.093 | | | | |
| CPT501 | 49.205 | 65.441 | 94.944 | | | |
| CPT503 | 52.831 | 85.017 | 82.112 | 184.252 | | |
| CPT601 | 39.667 | 64.825 | 61.153 | 86.537 | 132.116 | |
| CPT603 | 45.651 | 73.998 | 50.478 | 91.555 | 93.199 | 196.236 |

LISREL Estimates (Maximum Likelihood)

LAMBDA Y

| | ETA 1 | ETA 2 |
|---|---|---|
| CPT401 | 1.000 | 0.000 |
| CPT403 | 1.622 | 0.000 |
| CPT501 | 0.000 | 1.000 |
| CPT503 | 0.000 | 1.356 |
| CPT601 | 0.000 | 1.029 |
| CPT603 | 0.000 | 1.127 |

BETA

| | ETA 1 | ETA 2 |
|---|---|---|
| ETA 1 | 0.000 | 0.000 |
| ETA 2 | 0.727 | 0.000 |

PSI

| | ETA 1 | ETA 2 |
|---|---|---|
| ETA 1 | 54.553 | |
| ETA 2 | 0.000 | 31.572 |

## Appendix C.5 (continued)

### THETA EPS

| | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| CPT401 | 58.568 | | | | | |
| CPT403 | 0.000 | 30.485 | | | | |
| CPT501 | 9.140 | 0.000 | 34.550 | | | |
| CPT503 | 0.000 | 0.000 | 0.000 | 73.201 | | |
| CPT601 | 0.000 | 0.000 | 0.000 | 0.000 | 68.191 | |
| CPT603 | 0.000 | 0.000 | 17.343 | 0.000 | 22.685 | 119.186 |

Chi square with 5 degrees of freedom is 3.37 (p = 0.643).

## Appendix C.6

### Instruments Included in the LISREL Analyses

| Source | Variable | Subtest Name | Year |
|---|---|---|---|
| Parent Interview | | | |
| | SES3 | Educational aspirations | One |
| | SES4 | Educational expectations | One |
| | SES8 | Amount reading to child | One |
| | SES11 | Occupation head of household | One |
| | SES12 | Education of head of household | One |
| Johns Hopkins Perceptual Test | | | |
| | JHP101 | Perception | One |
| | JHP102 | Analysis | One |
| | JHP201 | Perception | Two |
| | JHP202 | Analysis | Two |
| Peabody Picture Vocabulary Test (Form A: Receptive) | | | |
| | PBA102 | Verbs | One |
| | PBA103 | Nouns | One |
| Peabody Picture Vocabulary Test (Form B: Productive) | | | |
| | PBB202 | Verbs | Two |
| | PBB203 | Nouns | Two |
| Cooperative Preschool Inventory | | | |
| | CLD201 | n/a | Two |
| Metropolitan Readiness Tests | | | |
| | MET301 | Word Meaning | Three |
| | MET302 | Listening | Three |
| | MET303 | Matching | Three |
| | MET304 | Alphabet | Three |
| | MET306 | Copying | Three |
| ETS Story Sequence | | | |
| | STY304 | Fluency Recall | Three |
| Cooperative Primary Tests | | | |
| | CPT401 | Reading | Four |
| | CPT403 | Word Analysis | Four |
| | CPT501 | Reading | Five |
| | CPT503 | Word Analysis | Five |
| | CPT601 | Reading | Six |
| | CPT603 | Word Analysis | Six |

## Appendix D.1

### Model One: Parent Interview and Years Two through Six -- Head Start Group

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES3 | 226 | 13.52 | 2.09 | -5.51 | 2.14 | -0.30 | 2.06 |
| SES4 | 202 | 12.02 | 1.84 | -2.19 | 2.16 | 0.63 | 0.67 |
| SES8 | 223 | 1.82 | 1.29 | -1.42 | 2.47 | 0.40 | -0.45 |
| SES11 | 226 | 7.02 | 2.19 | -3.21 | 1.36 | -0.57 | 0.60 |
| SES12 | 223 | 9.37 | 3.10 | -3.02 | 2.14 | -0.46 | -0.22 |
| CLD201 | 224 | 34.38 | 11.08 | -2.47 | 2.40 | -0.04 | -0.43 |
| CLD209 | 226 | 11.21 | 3.09 | -2.01 | 2.84 | 0.13 | -0.37 |
| JHP201 | 226 | 12.28 | 2.60 | -3.18 | 1.43 | -0.49 | -0.33 |
| JHP202 | 226 | 6.21 | 2.85 | -2.18 | 2.73 | 0.28 | -0.30 |
| MET301 | 226 | 6.77 | 3.02 | -2.24 | 3.05 | 0.59 | 0.31 |
| MET302 | 226 | 9.39 | 2.98 | -3.15 | 2.22 | -0.32 | 0.53 |
| MET303 | 226 | 6.97 | 3.43 | -2.03 | 2.05 | -0.15 | -0.66 |
| MET304 | 226 | 9.73 | 4.97 | -1.96 | 1.26 | -0.51 | -0.96 |
| MET306 | 226 | 3.83 | 3.03 | -1.26 | 3.36 | 0.92 | 0.70 |
| CPT401 | 226 | 18.51 | 9.21 | -2.01 | 3.20 | 0.80 | 1.52 |
| CPT403 | 226 | 27.97 | 10.43 | -2.68 | 2.59 | 0.09 | -0.02 |
| CPT501 | 226 | 20.27 | 8.15 | -2.49 | 2.79 | 0.14 | 0.48 |
| CPT503 | 226 | 38.66 | 12.66 | -3.05 | 1.61 | -0.68 | 0.47 |
| CPT601 | 226 | 24.55 | 11.57 | -2.12 | 2.11 | -0.30 | -0.35 |
| CPT603 | 226 | 40.59 | 15.22 | -2.67 | 1.28 | -1.08 | 0.76 |

## Appendix D.2

### Model Two: Parent Interview and Years Two and Three -- Head Start Group

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES3 | 349 | 13.58 | 2.08 | -5.55 | 3.08 | -0.01 | 1.05 |
| SES4 | 313 | 11.97 | 1.99 | -4.01 | 2.03 | 0.27 | 1.01 |
| SES8 | 340 | 1.77 | 1.34 | -1.32 | 2.42 | 0.46 | -0.51 |
| SES11 | 348 | 7.01 | 2.34 | -3.00 | 1.28 | -0.69 | 0.54 |
| SES12 | 345 | 9.49 | 3.00 | -3.17 | 2.84 | -0.53 | -0.06 |
| CLD201 | 345 | 32.90 | 11.90 | -2.60 | 2.45 | -0.08 | -0.62 |
| PIC209 | 348 | 11.17 | 3.06 | -2.34 | 2.88 | 0.15 | -0.26 |
| JHP201 | 349 | 12.17 | 2.67 | -3.81 | 1.44 | -0.59 | -0.03 |
| JHP202 | 349 | 6.13 | 2.75 | -2.23 | 2.86 | 0.27 | -0.34 |
| MET301 | 349 | 6.85 | 3.06 | -2.24 | 2.99 | 0.67 | 0.38 |
| MET302 | 349 | 9.22 | 2.93 | -3.14 | 2.31 | -0.24 | 0.24 |
| MET303 | 349 | 6.57 | 3.51 | -1.87 | 2.11 | -0.12 | -0.72 |
| MET304 | 349 | 9.15 | 5.15 | -1.77 | 1.33 | -0.34 | -1.19 |
| MET306 | 349 | 3.36 | 2.90 | -1.16 | 3.67 | 0.98 | 0.87 |
| STY302 | 349 | 18.19 | 25.95 | -0.70 | 2.69 | 2.29 | 3.33 |
| STY304 | 342 | 13.76 | 13.91 | -0.92 | 5.34 | 4.85 | 23.10 |

Appendix D.2 (continued)

Model Two: Parent Interview and Years Two and Three -- No Preschool Group

## UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES3 | 101 | 14.44 | 1.95 | -1.25 | 1.83 | -0.38 | -1.74 |
| SES4 | 89 | 12.58 | 1.64 | -2.18 | 2.08 | 0.98 | 0.40 |
| SES8 | 101 | 2.13 | 1.47 | -1.45 | 1.96 | 0.10 | -1.05 |
| SES11 | 102 | 6.17 | 2.95 | -2.09 | 1.30 | -0.37 | -0.57 |
| SES12 | 100 | 11.09 | 2.71 | -2.99 | 2.55 | -0.34 | 0.84 |
| CLD201 | 102 | 39.50 | 10.41 | -2.45 | 1.78 | -0.51 | -0.50 |
| PIC209 | 102 | 12.79 | 2.98 | -2.61 | 2.08 | -0.21 | -0.37 |
| JHP201 | 102 | 13.07 | 2.40 | -2.94 | 1.22 | -0.60 | -0.34 |
| JHP202 | 102 | 6.54 | 2.56 | -2.16 | 2.13 | 0.04 | -0.33 |
| MET301 | 102 | 8.26 | 4.05 | -2.04 | 1.91 | -0.08 | -0.20 |
| MET302 | 102 | 9.18 | 3.92 | -2.34 | 1.74 | -0.75 | 0.60 |
| MET303 | 102 | 6.93 | 3.79 | -1.83 | 1.87 | -0.14 | -1.13 |
| MET304 | 102 | 9.58 | 5.51 | -1.74 | 1.17 | -0.48 | -1.29 |
| MET306 | 102 | 3.71 | 3.18 | -1.17 | 2.92 | 0.80 | 0.17 |
| STY302 | 102 | 26.00 | 32.75 | -0.79 | 1.89 | 1.34 | -0.16 |
| STY304 | 97 | 14.85 | 13.47 | -0.73 | 5.43 | 4.93 | 23.94 |

## Appendix D.3

**Model Three: Parent Interview and Years Three and Four -- Head Start Group**

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES3 | 344 | 13.45 | 2.13 | -5.85 | 2.14 | -0.58 | 3.76 |
| SES4 | 310 | 11.80 | 2.02 | -4.85 | 2.07 | -0.09 | 2.39 |
| SES8 | 337 | 1.77 | 1.33 | -1.33 | 2.43 | 0.38 | -0.63 |
| SES11 | 343 | 7.08 | 2.23 | -3.18 | 1.31 | -0.71 | 0.87 |
| SES12 | 340 | 9.34 | 2.97 | -3.15 | 2.24 | -0.63 | -0.16 |
| MET301 | 344 | 6.80 | 3.12 | -2.18 | 2.95 | 0.68 | 0.44 |
| MET302 | 344 | 9.11 | 2.98 | -3.06 | 2.31 | -0.24 | 0.24 |
| MET303 | 344 | 6.47 | 3.50 | -1.85 | 2.15 | -0.07 | -0.72 |
| MET304 | 344 | 8.93 | 5.23 | -1.71 | 1.35 | -0.30 | -1.23 |
| MET306 | 344 | 3.29 | 2.91 | -1.13 | 3.68 | 1.00 | 0.90 |
| STY302 | 344 | 17.84 | 25.58 | -0.70 | 2.74 | 2.35 | 3.60 |
| STY304 | 336 | 13.58 | 13.43 | -0.79 | 5.54 | 5.03 | 25.07 |
| CPT401 | 344 | 17.36 | 9.36 | -1.86 | 3.38 | 0.69 | 1.48 |
| CPT403 | 344 | 25.81 | 11.20 | -2.30 | 2.61 | -0.03 | 0.01 |

Appendix D.3 (continued)

Model Three: Parent Interview and Years Three and Four -- No Preschool Group

UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES3 | 105 | 14.34 | 2.29 | -5.38 | 1.59 | -1.62 | 5.59 |
| SES4 | 95 | 12.58 | 1.66 | -2.16 | 2.06 | 1.06 | 0.43 |
| SES8 | 104 | 1.88 | 1.43 | -1.31 | 2.18 | 0.32 | -0.94 |
| SES11 | 106 | 6.65 | 2.73 | -2.44 | 1.23 | -0.45 | -0.29 |
| SES12 | 105 | 10.46 | 2.59 | -2.88 | 2.91 | -0.02 | 0.95 |
| MET301 | 106 | 8.00 | 3.84 | -2.08 | 2.08 | 0.07 | -0.04 |
| MET302 | 106 | 8.93 | 3.83 | -2.33 | 1.84 | -0.66 | 0.40 |
| MET303 | 106 | 6.53 | 3.69 | -1.77 | 2.03 | -0.07 | -0.94 |
| MET304 | 106 | 9.11 | 5.21 | -1.75 | 1.32 | -0.41 | -1.25 |
| MET306 | 106 | 3.17 | 2.98 | -1.06 | 3.30 | 0.79 | 0.06 |
| STY302 | 106 | 26.19 | 32.76 | -0.80 | 1.89 | 1.34 | -0.18 |
| STY304 | 102 | 15.25 | 15.05 | -0.61 | 4.83 | 4.40 | 18.40 |
| CPT401 | 106 | 16.47 | 10.51 | -1.57 | 3.00 | 0.56 | 0.75 |
| CPT403 | 106 | 26.65 | 12.69 | -2.10 | 2.31 | -0.15 | -0.30 |

## Appendix D.4

### Model Four: Years Three through Six -- Head Start Group

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| MET301 | 316 | 6.78 | 3.24 | -2.09 | 2.85 | 0.56 | 0.41 |
| MET302 | 316 | 9.35 | 3.10 | -3.02 | 2.15 | -0.28 | -0.35 |
| MET303 | 316 | 6.66 | 3.51 | -1.90 | 2.09 | -0.13 | -0.76 |
| MET304 | 316 | 9.69 | 4.98 | -1.95 | 1.27 | -0.48 | -0.99 |
| MET306 | 316 | 3.69 | 2.98 | -1.24 | 3.46 | 0.91 | 0.69 |
| CPT401 | 316 | 18.10 | 9.10 | -1.99 | 3.29 | 0.80 | 1.74 |
| CPT403 | 316 | 27.72 | 10.46 | -2.65 | 2.61 | 0.01 | 0.15 |
| CPT501 | 316 | 19.73 | 8.07 | -2.44 | 2.88 | 0.08 | 0.73 |
| CPT503 | 316 | 38.31 | 12.70 | -3.02 | 1.63 | -0.68 | 0.53 |
| CPT601 | 316 | 25.06 | 10.81 | -2.32 | 2.22 | -0.37 | -0.05 |
| CPT603 | 316 | 41.36 | 14.34 | -2.88 | 1.30 | -1.15 | 1.09 |

## Appendix D.4

### Model Four: Years Three through Six -- No Preschool

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| MET301 | 188 | 8.48 | 3.82 | -2.22 | 1.97 | -0.03 | -0.12 |
| MET302 | 188 | 9.26 | 3.41 | -2.71 | 1.98 | -0.98 | 1.17 |
| MET303 | 188 | 6.27 | 3.68 | -1.70 | 2.10 | -0.14 | -0.92 |
| MET304 | 188 | 9.53 | 5.20 | -1.83 | 1.24 | -0.43 | -1.07 |
| MET306 | 188 | 3.47 | 2.97 | -1.17 | 3.21 | 0.76 | 0.20 |
| CPT401 | 188 | 19.21 | 10.08 | -1.91 | 2.96 | 0.58 | 1.10 |
| CPT403 | 188 | 28.51 | 13.04 | -2.19 | 2.11 | -0.44 | -0.05 |
| CPT501 | 188 | 21.69 | 9.59 | -2.26 | 2.12 | -0.03 | -0.08 |
| CPT503 | 188 | 39.38 | 14.43 | -2.73 | 1.43 | -0.94 | 0.55 |
| CPT601 | 188 | 27.44 | 11.79 | -2.33 | 1.58 | -0.87 | 0.42 |
| CPT603 | 188 | 44.61 | 14.43 | -3.09 | 1.07 | -1.79 | 2.96 |

## Appendix D.5

### Model Five: Parent Interview and Years Five and Six -- Head Start Group

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| SES11 | 302 | 7.21 | 2.19 | -3.29 | 1.27 | -0.54 | 0.32 |
| SES12 | 299 | 9.44 | 2.96 | -3.19 | 2.22 | -0.59 | 0.02 |
| CPT501 | 305 | 19.60 | 8.11 | -2.42 | 2.89 | 0.03 | 0.69 |
| CPT503 | 305 | 37.47 | 12.46 | -3.01 | 1.73 | -0.51 | 0.23 |
| CPT601 | 305 | 24.28 | 10.95 | -2.22 | 2.26 | -0.28 | -0.09 |
| CPT603 | 305 | 39.75 | 15.08 | -2.64 | 1.34 | -1.00 | 0.62 |

## Appendix D.5 (continued)

**Model Five: Parent Interview and Years Five and Six -- No Preschool Group**

### UNIVARIATE SUMMARY STATISTICS

| Variable | Sample Size | Mean | Standard Deviation | Smallest Standard Score | Largest Standard Score | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|
| | | | No Preschool Group | | | | |
| SES11 | 118 | 6.07 | 2.84 | -2.14 | 1.39 | -0.36 | -0.43 |
| SES12 | 117 | 10.61 | 2.62 | -2.90 | 2.82 | 0.12 | 0.80 |
| CPT501 | 119 | 21.18 | 9.55 | -2.22 | 2.18 | 0.00 | 0.10 |
| CPT503 | 119 | 39.66 | 14.86 | -2.67 | 1.37 | -1.04 | 0.71 |
| CPT601 | 119 | 29.15 | 11.35 | -2.57 | 1.48 | -1.08 | 0.88 |
| CPT603 | 119 | 46.60 | 12.58 | -3.70 | 0.99 | -2.18 | 5.41 |

## Appendix E.1

### Model One: Parent Interview and Years Two through Six -- Head Start Group

### Covariance Matrix Analyzed

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | MET304 |
|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 4.375 | | | | | | | | | |
| SES4 | 1.999 | 3.455 | | | | | | | | |
| CLD201 | 8.089 | 7.703 | 122.575 | | | | | | | |
| PIC209 | 1.745 | 1.828 | 22.317 | 9.561 | | | | | | |
| JHP201 | 1.066 | 0.689 | 15.896 | 3.230 | 6.773 | | | | | |
| JHP202 | 0.685 | 0.320 | 12.487 | 2.525 | 3.100 | 8.124 | | | | |
| MET301 | 1.551 | 1.259 | 11.119 | 2.844 | 2.101 | 0.538 | 9.138 | | | |
| MET302 | 0.777 | 0.587 | 9.565 | 2.771 | 1.799 | 1.534 | 4.629 | 8.871 | | |
| MET303 | 2.034 | 0.967 | 12.961 | 3.611 | 2.071 | 0.771 | 3.580 | 3.630 | 11.772 | |
| MET304 | 1.400 | 1.692 | 24.173 | 5.368 | 3.158 | 2.787 | 5.105 | 4.953 | 7.009 | 24.671 |
| MET306 | 0.868 | 1.247 | 12.518 | 2.503 | 2.845 | 1.761 | 1.880 | 2.473 | 5.057 | 5.095 |
| CPT401 | 0.087 | 0.022 | 18.790 | 2.480 | 1.931 | 2.745 | 0.846 | 0.590 | 4.669 | 7.825 |
| CPT403 | 1.387 | 1.581 | 35.527 | 7.370 | 5.030 | 6.841 | 4.385 | 6.824 | 12.088 | 16.788 |
| CPT501 | 2.417 | 1.990 | 27.950 | 5.387 | 5.255 | 4.577 | 5.539 | 5.638 | 9.391 | 16.009 |
| CPT503 | 4.444 | 3.317 | 55.883 | 9.840 | 10.546 | 8.237 | 11.846 | 12.841 | 16.292 | 26.431 |
| CPT601 | 5.968 | 4.665 | 52.388 | 10.903 | 9.088 | 5.176 | 6.393 | 7.050 | 11.750 | 19.280 |
| CPT603 | 2.561 | 5.333 | 50.031 | 9.593 | 8.375 | 6.412 | 6.407 | 5.669 | 11.885 | 19.611 |
| SES11 | -0.703 | -0.984 | -4.870 | -1.741 | -0.414 | -0.466 | -0.707 | -0.838 | -0.466 | -1.715 |
| SES12 | 1.901 | 2.120 | 12.591 | 3.139 | 1.106 | 0.102 | 2.064 | 0.894 | 1.226 | 3.095 |

| | MET306 | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 | SES11 | SES12 |
|---|---|---|---|---|---|---|---|---|---|
| MET306 | 9.166 | | | | | | | | |
| CPT401 | 5.693 | 84.909 | | | | | | | |
| CPT403 | 12.355 | 54.591 | 108.870 | | | | | | |
| CPT501 | 8.461 | 9.611 | 29.767 | 66.476 | | | | | |
| CPT503 | 15.772 | 27.636 | 66.595 | 61.009 | 160.279 | | | | |
| CPT601 | 12.953 | 18.622 | 32.970 | 40.307 | 72.339 | 133.875 | | | |
| CPT603 | 13.186 | 35.024 | 52.176 | 27.056 | 81.228 | 113.862 | 231.772 | | |
| SES11 | -0.357 | 1.329 | -1.333 | -2.356 | -3.354 | -2.934 | -0.962 | 4.791 | |
| SES12 | 1.179 | 1.502 | 2.850 | 3.705 | 7.954 | 8.409 | 7.896 | -2.020 | 9.593 |

## Appendix E.2

### Model Two: Parent Interview and Years Two and Three -- Head Start Group

### Covariance Matrix Analyzed

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | MET304 |
|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 4.343 | | | | | | | | | |
| SES4 | 2.201 | 3.971 | | | | | | | | |
| CLD201 | 8.022 | 9.439 | 141.183 | | | | | | | |
| PIC209 | 1.540 | 1.846 | 22.745 | 9.384 | | | | | | |
| JHP201 | 1.328 | 1.249 | 18.625 | 3.477 | 7.112 | | | | | |
| JHP202 | 0.721 | 0.636 | 14.341 | 2.580 | 3.446 | 7.554 | | | | |
| MET301 | 1.391 | 1.029 | 12.884 | 2.600 | 2.388 | 0.961 | 9.350 | | | |
| MET302 | 0.723 | 0.351 | 9.337 | 2.390 | 1.675 | 1.102 | 4.187 | 8.609 | | |
| MET303 | 1.508 | 1.192 | 16.426 | 3.457 | 2.696 | 1.290 | 2.977 | 3.741 | 12.349 | |
| MET304 | 1.660 | 2.222 | 28.579 | 5.173 | 4.056 | 2.952 | 4.753 | 5.755 | 8.956 | 26.573 |
| MET306 | 0.761 | 1.325 | 14.823 | 2.419 | 2.688 | 1.799 | 1.930 | 2.333 | 4.728 | 6.294 |
| SES11 | -0.479 | -0.588 | -4.849 | -1.299 | -0.465 | -0.059 | -0.575 | -0.394 | -0.592 | -1.760 |
| SES12 | 1.747 | 1.897 | 11.947 | 2.932 | 1.248 | 0.278 | 1.868 | 0.491 | 0.866 | 2.274 |

| | MET306 | SES11 | SES12 |
|---|---|---|---|
| MET306 | 8.410 | | |
| SES11 | -0.230 | 5.471 | |
| SES12 | 0.564 | -1.870 | 8.966 |

## Appendix E.2 (continued)

## Model Two: Parent Interview and Years Two and Three -- No Preschool Group

### Covariance Matrix Analyzed

| | SES3 | SES4 | CLD201 | PIC209 | JHP201 | JHP202 | MET301 | MET302 | MET303 | MET304 |
|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 3.805 | | | | | | | | | |
| SES4 | 1.008 | 2.653 | | | | | | | | |
| CLD201 | 0.082 | 2.885 | 108.391 | | | | | | | |
| PIC209 | -0.465 | -0.122 | 17.817 | 8.898 | | | | | | |
| JHP201 | 0.717 | 0.539 | 8.480 | 2.529 | 5.768 | | | | | |
| JHP202 | 0.156 | 0.430 | 4.480 | 1.399 | 2.557 | 6.568 | | | | |
| MET301 | 0.080 | 0.416 | 7.530 | 0.728 | 0.388 | -0.897 | 16.395 | | | |
| MET302 | 0.675 | 0.198 | 6.584 | -0.092 | 0.592 | -1.314 | 12.725 | 15.335 | | |
| MET303 | 0.480 | 1.128 | 16.579 | 4.204 | 2.965 | 0.453 | 4.840 | 4.765 | 14.342 | |
| MET304 | 1.926 | 2.242 | 29.163 | 5.308 | 4.009 | 0.556 | 6.024 | 5.372 | 11.099 | 30.306 |
| MET306 | 0.478 | 0.998 | 17.371 | 3.396 | 2.861 | 0.858 | 3.482 | 3.684 | 6.357 | 7.265 |
| SES11 | -0.991 | -1.863 | -9.569 | -1.757 | -1.190 | -0.447 | -3.351 | -2.228 | -3.642 | -5.246 |
| SES12 | 0.896 | 1.753 | 7.075 | 0.658 | 1.079 | 1.282 | 0.658 | 0.874 | 3.140 | 5.374 |

| | MET306 | SES11 | SES12 |
|---|---|---|---|
| MET306 | 10.106 | | |
| SES11 | -3.774 | 8.695 | |
| SES12 | 2.167 | -4.703 | 7.322 |

## Appendix E.3

### Model Three: Parent Interview and Years Three and Four -- Head Start Group

### Covariance Matrix Analyzed

| | SES3 | SES4 | MET301 | MET302 | MET303 | MET304 | MET306 | CPT401 | CPT403 | SES11 | SES12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 4.534 | | | | | | | | | | |
| SES4 | 2.415 | 4.109 | | | | | | | | | |
| MET301 | 1.761 | 1.432 | 9.758 | | | | | | | | |
| MET302 | 1.045 | 0.832 | 4.527 | 8.894 | | | | | | | |
| MET303 | 1.989 | 1.718 | 3.327 | 4.233 | 12.250 | | | | | | |
| MET304 | 2.043 | 2.712 | 4.963 | 6.264 | 9.062 | 27.360 | | | | | |
| MET306 | 1.039 | 1.698 | 2.394 | 2.620 | 5.016 | 6.714 | 8.481 | | | | |
| CPT401 | -0.630 | 0.060 | 0.677 | 1.930 | 6.344 | 9.553 | 6.678 | 87.526 | | | |
| CPT403 | 0.644 | 2.942 | 4.384 | 8.045 | 14.601 | 22.479 | 14.497 | 58.876 | 125.347 | | |
| SES11 | -0.617 | -0.556 | -0.529 | -0.425 | -0.535 | -1.709 | -0.396 | 0.431 | -1.412 | 4.977 | |
| SES12 | 1.886 | 1.929 | 1.924 | 0.765 | 1.088 | 2.476 | 0.855 | 0.144 | 1.196 | -1.655 | 8.783 |

Appendix E.3 (continued)

Model Three: Parent Interview and Years Three and Four -- No Preschool Group

Covariance Matrix Analyzed

| | SES3 | SES4 | MET301 | MET302 | MET303 | MET304 | MET306 | CPT401 | CPT403 | SES11 | SES12 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SES3 | 5.260 | | | | | | | | | | |
| SES4 | 0.674 | 2.710 | | | | | | | | | |
| MET301 | 0.116 | 0.252 | 14.781 | | | | | | | | |
| MET302 | 0.517 | 0.423 | 11.057 | 14.672 | | | | | | | |
| MET303 | 0.776 | 0.681 | 5.114 | 5.883 | 13.604 | | | | | | |
| MET304 | 1.827 | 1.402 | 5.648 | 6.322 | 9.987 | 27.130 | | | | | |
| MET306 | 0.860 | 0.491 | 2.629 | 3.107 | 5.605 | 5.571 | 8.885 | | | | |
| CPT401 | -1.453 | 2.335 | 6.571 | 2.050 | 10.482 | 14.613 | 7.348 | 110.442 | | | |
| CPT403 | -0.029 | 3.813 | 5.629 | -2.442 | 14.777 | 11.011 | 12.546 | 94.652 | 161.087 | | |
| SES11 | 0.203 | -1.532 | -2.524 | -2.357 | -2.642 | -3.732 | -2.959 | -6.434 | -8.609 | 7.448 | |
| SES12 | 0.668 | 1.537 | 0.588 | 0.930 | 2.382 | 3.202 | 1.666 | 2.828 | 6.756 | -3.305 | 6.708 |

## Appendix E.4

### Model Four: Years Three through Six -- Head Start Group

### Covariance Matrix Analyzed

| | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 | MET303 | MET304 | MET306 | MET301 | MET302 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CPT401 | 82.768 | | | | | | | | | | |
| CPT403 | 54.577 | 109.414 | | | | | | | | | |
| CPT501 | 14.608 | 30.248 | 65.126 | | | | | | | | |
| CPT503 | 26.576 | 65.112 | 59.155 | 161.205 | | | | | | | |
| CPT601 | 18.852 | 36.181 | 38.168 | 67.925 | 116.771 | | | | | | |
| CPT603 | 30.618 | 53.813 | 27.366 | 78.795 | 99.284 | 205.642 | | | | | |
| MET303 | 5.477 | 11.751 | 10.385 | 15.666 | 11.016 | 11.446 | 12.293 | | | | |
| MET304 | 8.808 | 16.190 | 15.509 | 23.823 | 18.519 | 21.078 | 7.759 | 24.818 | | | |
| MET306 | 5.910 | 11.817 | 8.013 | 13.996 | 11.510 | 13.114 | 5.053 | 5.763 | 8.863 | | |
| MET301 | 0.038 | 1.579 | 4.663 | 8.275 | 5.343 | 5.246 | 3.729 | 6.014 | 1.889 | 10.471 | |
| MET302 | 1.098 | 5.324 | 5.424 | 10.163 | 6.050 | 5.290 | 3.948 | 5.888 | 2.143 | 5.730 | 9.582 |

## Appendix E.4 (continued)

### Model Four: Years Three through Six -- No Preschool Group

### Covariance Matrix Analyzed

| | CPT401 | CPT403 | CPT501 | CPT503 | CPT601 | CPT603 | MET303 | MET304 | MET306 | MET301 | MET302 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| CPT401 | 101.609 | | | | | | | | | | |
| CPT403 | 69.012 | 170.005 | | | | | | | | | |
| CPT501 | 37.504 | 44.539 | 91.917 | | | | | | | | |
| CPT503 | 38.722 | 54.934 | 74.271 | 208.120 | | | | | | | |
| CPT601 | 18.583 | 38.548 | 44.774 | 80.014 | 138.910 | | | | | | |
| CPT603 | 30.765 | 47.470 | 30.295 | 89.337 | 66.122 | 208.335 | | | | | |
| MET303 | 6.297 | 7.480 | 6.100 | 14.288 | 3.712 | 16.794 | 13.576 | | | | |
| MET304 | 8.413 | 6.965 | 16.457 | 30.357 | 14.441 | 28.379 | 9.409 | 27.010 | | | |
| MET306 | 4.079 | 8.516 | 8.249 | 17.274 | 9.741 | 12.439 | 4.624 | 5.771 | 8.839 | | |
| MET301 | 5.541 | 7.128 | 5.618 | 8.092 | 4.312 | 10.777 | 5.197 | 7.078 | 2.184 | 14.572 | |
| MET302 | 4.888 | 3.972 | 4.867 | 7.998 | 2.107 | 8.950 | 5.563 | 5.377 | 1.912 | 8.919 | 11.646 |

## Appendix E.5

### Model Five: Head Start Group

Covariances

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| SES11 | 4.791 | | | | | |
| SES12 | -1.646 | 8.744 | | | | |
| CPT501 | -2.225 | 2.103 | 65.695 | | | |
| CPT503 | -3.576 | 5.775 | 53.206 | 155.177 | | |
| CPT601 | -2.288 | 7.057 | 36.137 | 63.492 | 119.953 | |
| CPT603 | -0.860 | 6.230 | 29.214 | 76.030 | 105.594 | 227.321 |

Moment Matrix Analyzed

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 | DUMMY |
|---|---|---|---|---|---|---|---|
| SES11 | 56.847 | | | | | | |
| SES12 | 66.393 | 97.606 | | | | | |
| CPT501 | 139.193 | 186.857 | 449.511 | | | | |
| CPT503 | 266.812 | 359.019 | 787.298 | 1558.583 | | | |
| CPT601 | 172.939 | 235.968 | 511.865 | 973.101 | 709.174 | | |
| CPT603 | 285.963 | 380.956 | 808.040 | 1565.075 | 1070.396 | 1806.443 | |
| DUMMY | 7.216 | 9.428 | 19.597 | 37.469 | 24.282 | 39.748 | 1.000 |

## Appendix E.5 (continued)

### Model Five: No Preschool Group

Covariances

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 |
|---|---|---|---|---|---|---|
| SES11 | 8.039 | | | | | |
| SES12 | -2.365 | 6.853 | | | | |
| CPT501 | -5.720 | 3.192 | 91.231 | | | |
| CPT503 | -14.015 | 9.156 | 79.594 | 220.801 | | |
| CPT601 | -6.338 | 5.944 | 50.990 | 96.153 | 128.774 | |
| CPT603 | -5.772 | 5.903 | 30.216 | 105.363 | 74.799 | 158.327 |

Moment Matrix Analyzed

| | SES11 | SES12 | CPT501 | CPT503 | CPT601 | CPT603 | DUMMY |
|---|---|---|---|---|---|---|---|
| SES11 | 44.719 | | | | | | |
| SES12 | 61.889 | 119.076 | | | | | |
| CPT501 | 122.700 | 227.556 | 538.907 | | | | |
| CPT503 | 226.545 | 429.367 | 918.866 | 1792.168 | | | |
| CPT601 | 170.430 | 314.788 | 667.882 | 1251.597 | 977.488 | | |
| CPT603 | 276.745 | 499.602 | 1016.714 | 1952.681 | 1432.521 | 2328.243 | |
| DUMMY | 6.062 | 10.596 | 21.176 | 39.664 | 29.151 | 46.597 | 1.000 |

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