THE ROLE OF HIGHER-ORDER COGNITIVE ABILITIES AS MEDIATORS OF DEFICITS IN ACADEMIC PERFORMANCE

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ABSTRACT: The questions in this study were three-fold. The first question, suggested by the work of Das and Naglieri (e.g., Naglieri & Das 1987, 1988), addressed the hypothesis that a higher-order structure underlies performance on a battery of cognitive tests. The second question, concerned with external validity, addressed how well the higher-order cognitive ability factors predict two criterion-related measures of ability, Academic Achievement and Word Skills. The third question, also concerned with external validity, addressed whether differences between students classified as low or normal in reading achievement were mediated by individual differences in the higher-order ability factors. That is, do the hypothesized higher-order cognitive abilities play a mediating role in predicting deficits in academic achievement and reading competence? Structural equation modeling techniques were used to test these research hypotheses on a stratified random sample of 135 third grade students. The first stratum contained a random selection of 69 students classified as low in reading achievement based on the Chapter 1 entitlement assignments made by the school district the year prior to the study and the second stratum contained 66 students selected from the normal achieving population. The results showed that (a) two higher-order factors, Planning/Attention and Successive Processing, explained the relations among six lower-order ability constructs, (b) the higher-
order ability factors predicted individual differences in the two criterion measures of Academic Achievement and Word Skills, and, (c) low achieving students showed significant deficits only in the two higher-order factors, suggesting a mediating role for the cognitive skills represented by the higher-order factors.

INTRODUCTION

The relationship between intelligence (IQ) and school achievement, including the acquisition of early reading skills, is far from perfect (Sattler 1988). Agglomerative IQ measures provide little insight into the cognitive processes involved in academic achievement or the acquisition of reading skills. Assuming that learning disabled and underachieving children do poorly on achievement tests because of their weaknesses in specific cognitive processes, characterizing their intellective behavior in terms of global IQ does not assist in identifying the sources of deficits in their academic performance. Potentially more informative approaches to understanding intelligence have emerged recently that have focused on representing intellective behavior as a constellation of cognitive processes (e.g., Das 1973; Horn 1982, 1986, 1988; Sternberg 1986, 1990). The purpose of the current investigation is to explore the component structure and subsequent role of basic cognitive processes as mediators of identified deficits in academic performance; that is, can the individual differences in academic performance deficits be explained by the pattern of individual differences in the component processes of intellective functioning?

In the present article we consider a subset of the four different cognitive processes from the PASS model of intelligence (e.g., Naglieri & Das 1987, 1988) as mediators of performance deficits on tests of academic achievement and reading skills. The four processes of the PASS model that have been identified are: Planning, Attention, Simultaneous, and Successive coding of information (Das, Kirby, & Jarman 1975, 1979; Naglieri & Das 1990). The PASS model is based on Luria's (e.g., 1966, 1980) conception of the brain and the three interactive functional units of human cognitive processes which he hypothesized.

The first functional unit regulates mental activity and attention; it is governed by the reticular formation. This functional unit is involved in the coordination of attentional skills toward the solution of multidimensional tasks, such as a Stroop test (e.g., Golden 1978). The second functional unit codes and processes simultaneous and successive information. Simultaneous processes are involved in performing tasks that involve grouping information such as on Raven matrices and some Piagetian tasks which assess such skills as conservation, seriation, and higher-order classification (Carlson & Wiedl 1979). Successive processes are required to solve tasks that, without the advantage of oversight of the total series, require a series of steps to arrive at a solution. Thus, successive processes are involved in tasks that require linear processing such as are found in serial recall
tests of memory. The third functional unit involves planning and impulse control. Planning is represented by abilities to plan, problem solve, and monitor one's cognitive activity in such tasks as planned connections and visual search (Naglieri & Das 1988). All three functional units are interdependent; for example, planning (functional unit 3) is closely related to arousal and allocation of attentional resources (functional unit 1). Planning is also dependent upon information that has been simultaneously or successively coded (functional unit 2).

From these three functional units hypothesized by Luria, Das (1973) and his colleagues (e.g., Das et al. 1975, 1979) initially explored the second functional unit by studying the nature of simultaneous and successive processes. This early work of Das et al. (e.g., 1979) supported a bi-dimensional operationalization of Luria's second functional unit. Later, conceptualizations of planning (functional unit 3) and attention (functional unit 1; see e.g., Naglieri & Das 1990) were added to the model.

The four PASS processes have been shown to be more informative of intellectual capability than general mental ability measured by standard intelligence tests. For example, Naglieri, Das, Stevens, & Ledbetter (1990) conducted a confirmatory factor analysis of the structure among a number of tests and concluded that four factors representing the four PASS processes provided the best fit to the data. Competing models, such as a 'g' model and a verbal/nonverbal structure, were less consistent with the data. However, the relations among some of the four PASS factors demonstrated a high degree of intercorrelation (e.g., planning and attention; see Naglieri et al.). Because of the design of the analyses, Naglieri et al. did not explore whether a higher-order structure would explain the relations among the PASS factors.

Various components of the PASS model have been used to study their predictive utility. For example, tests of Expressive Attention and two of Successive Processing (Sequence Repetition and Speech Rate) have been identified as correlates of reading competence when IQ was covaried (Das, Mensink, & Mishra 1990); further, these tests and others, such as Selective Attention, Word Series, and Sentence Repetitions, have been used in previous studies for predicting school achievement (Das & Mishra 1991; Naglieri & Das 1990). Measures of successive processing have been used to predict word decoding and reading comprehension (Das & Cummins 1982; Leong 1984). In addition, tests of planning ability have been found to be related to reading comprehension measures (Naglieri & Das 1987) as well as mathematics achievement (Garofalo 1986), with the magnitude of these relationships increasing from grade 2 through grade 6 (Naglieri & Das 1987). However, in none of these studies were the relationships tested simultaneously as higher-order and lower-order abilities such that the theoretical structure and relative importance of the various PASS components could be evaluated.

Given the preceding discussion of the PASS model, the main goals of the present study were three-fold. First, we wanted to provide a more definitive test of the hypothesized higher-order structure among six lower-order constructs representing three of the cognitive processing domains from the PASS model.
Although not all the PASS factors were testable given the available data, the data set did provide sufficient information to evaluate a subset of the hypothesized processes. Specifically, three lower-order constructs from the successive processing domain were predicted to form a higher-order Successive Processing factor. Two lower-order constructs representing attentional skills and one lower-order construct representing planning were predicted to form a higher-order factor of Planning/Attention. The agglomeration of planning and attention was hypothesized based on previous findings that showed a high degree of correlation and thus lack of differentiation between the two constructs of planning and attention (e.g., Naglieri et al. 1990). We thus hypothesized that the three lower-order constructs would be sufficient to identify a more heterogeneous higher-order construct of Planning/Attention; however, such a heterogeneous factor provides only partial support for the two constituent constructs of Planning and Attention—a stronger assessment would require more measures of each construct.

Methodologically, we chose to represent the cognitive measures as lower-order and higher-order factors to allow all potential sources of reliable variance to be represented in the model and to allow a direct statistical test of our hypothesized higher-order structure. For example, if our hypothesis regarding the agglomeration of planning and attention were incorrect, then reliable disturbances from the lower-order planning factor should show differential patterns of relations with other measures in the model. In this manner, we were able to test whether our hypothesized structure was able to represent adequately the relations among the lower-order constructs. Further, tests of other higher-order structures, such as a ‘g’ model, could be contrasted in a direct manner.

Employing the method of concurrent, criterion-related validity, a second question of the present study examined the relations among the higher-order ability factors with two outcome constructs representing academic performance: academic achievement and basic reading skills. With the inclusion of these outcome measures, we wanted to evaluate the utility of the hypothesized higher-order ability factors as predictors of individual differences in academic achievement and basic reading skills. We were interested particularly in the potential differential relationship between the higher-order and lower-order constructs in their ability to predict general reading and mathematics achievement and word decoding skills. If direct effects from the lower-order constructs to the outcome measures were exhibited, then the proposed higher-order structure would be unnecessary for capturing the meaningful relations among the cognitive processes. On the other hand, if no direct effects from the lower-order constructs were necessary and the higher-order factors predicted patterns of individual differences in the outcome measures, then the proposed higher-order structure would reflect well, and in accordance with our predictions, the important individual differences inherent in the lower-order cognitive processes.

The third theoretical question was asked using another form of external validation and explored the effects of identified deficiencies in reading achievement. Specifically, we wanted to know whether differences between students
identified as low or normal in reading achievement are mediated by individual differences in the higher-order ability factors. Accordingly, the sample comprised two stratified subgroups of elementary school children: those designated by the school district to receive special services based on low achievement scores and those who were considered to be achieving at a normal or expected level. Low reading achievement students were those students who scored below the 30th percentile on the reading subtest of the Stanford Achievement Test that was given the preceding year. Again, for the hypothesized structure among the cognitive processing constructs to be maximally useful, the expected deficits for the low reading achievement students in the two outcome measures of academic performance should be mediated by concomitant deficits in the higher-order ability factors. On the other hand, the group classification based on exhibited reading deficiencies may show direct effects on the outcome factors, the lower-order factors, or both. If such were the case, then the hypothesized higher-order ability structure would be of little utility for representing the sources of deficits for these two groups of children.

METHODS

SUBJECTS

135 (73 females) third grade subjects were included in the analyses. These students were randomly selected from two groups of students who were classified as either low or normal in reading achievement. The low reading achievement classification was determined on the part of the school district for the year prior to the study and was defined as those students who score at or below the 30th percentile on the reading subtest of the Stanford Achievement Test which, again, was administered during the preceding school year. The low reading achievement classification qualified the children for special services under the Chapter I categorical entitlement program in the state of California. Thus the stratified random sample of 135 subjects included 69 (36 females) subjects who were selected from the low reading achievement students (low achieving) and the remaining 66 (35 females) subjects were selected from the normal reading achievement students (normal achieving).

DESCRIPTION OF THE MEASURES

The administered version of the Das-Naglieri Cognitive Assessment System (DN-CAS; Naglieri & Das 1987, 1988) was comprised of 10 tests of cognitive processing, representing the four PASS domains described above. Subjects were tested individually by a trained examiner. The test battery included one test from the Planning domain (Planned Connections), two from the Attention domain
(Selective Attention and Expressive Attention), four from the Successive Processing domain (Sequence Repetitions, Word Series, Sentence Repetitions, and Speech Rate) and three from the Simultaneous Processing domain. For all tests, internal consistency reliability (ICR) estimates (Cronbach 1951) were calculated using a SAS/IML adaptation of the reliability program developed by Widaman and Hays (1986). However, because the tests of the Simultaneous domain showed very low levels of reliability and essentially no variation because of pronounced floor and ceiling effects evinced for the whole sample, they were excluded from further consideration; thus, only 7 of the 10 tests were evaluated in this study.2

When necessary, items from each test were aggregated into composite indicators for the structural modeling analyses. Creation of aggregate indicators, or parcels, involved the systematic construction of linear composites of items from each of the tests described below. Combining items into groups of two or three parcels of items to represent each construct provides higher levels of reliability per indicator and, yet, still allows for common variance among a set of items to identify an underlying factor. Forming parcels amplifies what the items have in common relative to their unique specificities. Thus, the parcelling of items was done in order to measure the underlying cognitive skill inherent in each test with multiple indicators at the latent level (Widaman & Kishton forthcoming). By using two or three parcels of items to identify each of the latent factors, only the reliable, shared variance of the indicators is represented at the latent level (Jöreskog & Sörbom 1989; Widaman & Kishton forthcoming). Four important features of using multiple indicators for each test are that (a) the type of cognitive processing component measured by each test can be represented as a latent factor in the models, (b) this information is represented as reliable variance only (i.e., the information is disattenuated or corrected for unreliability), (c) direct statistical comparisons of competing higher-order models are made possible and (d) any significant and reliable relationship between the lower-order constructs and the outcome constructs, which is not mediated by the higher-order constructs, can be discovered and estimated.

**Selective Attention.** For the Selective Attention test, a child must listen to 5 1-minute recordings of 10 stimulus words that are presented randomly at a rate of 1 per second. The 10 stimulus words belong to two categories, either furniture words (bed, chair, lamp, table, and sofa) or animal words (cat, dog, mouse, tiger, rabbit). Further, the words are spoken by either a male or female voice which was also randomly determined. On each of the 5 trials, a child must identify, by tapping on the table, each time he or she hears a furniture word spoken by a woman or an animal word spoken by a man. Thus, this test is an auditory Stroop-like test that requires considerable attentional capacity to identify correctly the target words spoken by the target voice. Each of the 5 trials was scored as the number of correct responses (maximum possible was 15). Trials 1 and 5 were averaged as one indicator, trials 2 and 4 as a second, and trial 3 was used as the third indicator. The ICR of this test was .87.
Planned Connections. For the Planned Connections test, a child must trace in sequential order the connections between stimuli that are arrayed diversely upon a page. For the first two of the four Planned Connections items, the stimuli are numbers; for the last two items, the stimuli are alternating numbers and letters (e.g., 1 to A, A to 2, 2 to B, B to 3, and so on). Only the last two complex Planned Connection items were used in the analyses because the first two items showed no variation and involved only a simple recitation of the number series. On the other hand, the two complex items of this test require both planning and monitoring. Possible strategies for these items include scanning the page item-by-item, scanning for the next few letters and numbers, repeating either silently or aloud the alphabet and number series, as well as monitoring the previous letters and numbers in order to know what comes next in the sequence and which sequence is next in the alternating of sequences. The two complex items of the Planned Connections test are scored as the time required to complete the connections. The ICR for the two indicators was .80.

Expressive Attention. For the Expressive Attention test, a child must state the color of a presented stimulus. The stimuli are grouped into three blocks of 40 items. The first block of forty stimuli consist of words which correspond with the color name of the color to be stated. The second block of 40 stimuli consist of arrays of colored triangles. The final block of 40 stimuli consist of color names that are printed in a color that is different from the printed name, thus creating a Stroop-like attentional demand (Golden 1978). For each of the three blocks of stimuli, four colors (and color names when appropriate) are used: red, yellow, blue, and green. Each of the three blocks of items was scored as the response time divided by the number of correct responses. Blocks 1 and 2 were aggregated into one indicator and block 3 was used as the second. The ICR of this test was at a moderate level, .72.

Word Series and Sentence Repetition. The Word Series and Sentence Repetition tests are two tests of nearly identical demands; both are memory span tests with serial recall and both clearly represent the linearity requirement of the successive processing paradigm (Naglieri & Das 1990). In the Word Series test, single syllable word lists are read at a rate of one per second; the list sizes range from two to nine words. In the Sentence Repetition test, sentences of minimal meaningfulness (i.e., substituting color words in place of verbs, nouns, adverbs, etc.) are read at a rate of one word per second and the subject is required to provide a serial recall of the sentence. Given the similarity of cognitive demand as well as the common covariation among the indicators (which evinced only a single factor in preliminary analyses), these two tests were combined in the analyses. Each item for both tests was scored as correct or incorrect. Items from each test were assigned to the first parcel, items 2, 5, 8, etc. were assigned to the second parcel, and items 3, 6, 9, etc. were assigned to the third parcel. The ICR for each test separately was .84 and combined was .85.
Speech Rate. For the Speech Rate test, a child must repeat a triad of one-, two-, or three-syllable words as fast as possible for 10 repetitions. Six trials are given: the first two trials with one-syllable words, the next two trials with two-syllable words, and the last two trials with three-syllable words. The time to complete the 10 repetitions on each trial was recorded as the dependent measure. Trials 1, 3, and 5 were aggregated into one indicator and trials 2, 4, and 6 were aggregated into the second. The ICR for this scale was .79.

Sequence Repetition. The last test selected from the DN-CAS battery was the Sequence Repetition test. For the Sequence Repetition test, a child must listen to a designated sequence of two nonsense words (gouch and lipe) and repeat the sequence ten times in succession. The first three sequences consist of four items each (e.g., gouch, gouch, lipe, gouch) and the last two sequences consist of five items each. The time to complete the repetitions was recorded in seconds for each of the 5 items. Sequences 1, 3, and 5 formed one indicator and sequences 2 and 4 formed the second. The ICR for this scale was .78.

Academic Achievement. The scores from the school administered Stanford Achievement Test (SAT; Madden, Gardner, Rudman, Karlsen, & Merwin 1974) were included as concurrent criterion-related measures of academic performance. Both the mathematics and reading subscales were used as indicators of overall academic achievement. The ICR for the two indicators was .89.

Word Skills. Two additional concurrent criterion-related measures of basic word skills were administered in the form of the Word Attack and Letter-Word Identification subtests of the Woodcock Reading Mastery battery (Woodcock 1987). In the Word Attack test, a child is given a list of 26 nonsense words and is asked to read them aloud. In the Letter-Word Identification Test, a child is given a list of 54 actual words and is asked to read them aloud. Both tests were scored as the number of items pronounced correctly. The ICR for the two indicators was .94.

Treatment of the Data

Very few of the items in the analyses had missing data. Overall, only 2.3% of the responses were missing and these values were replaced using regression techniques to estimate any missing value from non-missing items. Assessments of the distributional characteristics (e.g., skewness, outliers) of the variables in the data set were conducted for each of the indicators of the lower-order constructs at the item level when items were used and at the parcel level when parcels were used.

Each of the response time indicators demonstrated slightly positively skewed distributions, thus the square-roots of the indicators were taken in order to normalize the distributions (Tabachnick & Fidell 1989). Also because the metrics
of the scales varied from test to test, the indicators were standardized to a mean of 10 and a standard deviation of 2.

Outliers for each of the indicators were identified through regression techniques (see Tabachnick & Fidell 1989). Specifically, each indicator was predicted by the set of remaining indicators used in the analyses. Any value falling outside the 99% isodensity contour (i.e., the conditional confidence interval) of the regression equation was deemed an outlier and was replaced with a value that was at the 95% isodensity contour for the same equation. Overall less than 3% of the 2,412 data points were adjusted as outliers.

Analytic Procedures

The structural modeling analyses specified four basic models to evaluate the three hypotheses outlined above. For each of the models tested, two measures of model fit were used: the maximum likelihood $\chi^2$ statistic and the Tucker-Lewis $Rho$ coefficient. The $\chi^2$ statistic measures the statistical significance of the difference between the original and reproduced covariance matrices (Jöreskog & Sörbom 1989); thus, a non-significant $\chi^2$ value is desired. The Tucker-Lewis $Rho$ coefficient (also termed NNFI, or non-normed fit index; see, Bentler & Bonett 1980; Marsh, Balla, & McDonald 1988; Tucker & Lewis 1973) assesses the practical level of fit for a specified model. The practical level of fit indexed by the $Rho$ coefficient is the proportion of fit gained relative to a Null hypothesis model that specifies no relations among the measured variables. Tucker and Lewis suggested that a $Rho$ value of .95 or greater is a sufficient increase in the relative fit between the Null model and the specified alternative to accept the alternative model as being an adequate representation of the underlying structure among the measured variables.

The Measurement Model. The first substantive model specified was the measurement model. This model allowed estimates for only the hypothesized pattern of factor loadings; specifically, each indicator for a given construct was allowed to load only on the hypothesized latent factor. This measurement model also allowed each factor to inter-correlate freely. Thus, the measurement model represents an oblique nine factor solution with an idealized simple structure for the factor pattern.3

The first factor of the measurement model was a dichotomously coded factor termed Low Achieving. This factor was specified by fixing the residual of the dummy coded measured variable at 0.0, thus, all the variance associated with the low achieving classification is represented at the latent variable level. The measure variable and, thus, the Low Achieving factor, was coded as a 1 for subjects identified as low achieving in reading and as a 0 for subjects who were normal achieving. Regarding the three lower-order factors from the Planning and Attention domains, three indicators were used to identify the Selective Attention factor and two indicators were used to identify each of the Planned
Connections and Expressive Attention factors, respectively. Regarding the three lower-order factors from the Successive Processing domain, three parcels were used to identify the Word and Sentence Repetition factor and two indicators were used to identify each of the Speech Rate and Sequence Repetition factors, respectively. The two outcome factors were identified by two indicators each: For the Academic Achievement factor, the scores on Reading and Mathematics Achievement were used; for the Word Skills factor, the scores on the two Woodcock Reading Mastery subscales, Letter-Word Identification and Word Attack, were used. The accuracy of this model as well as the models to be described below was evaluated based on the two fit statistics ($\chi^2$ and $Rho$) and the modification indices provided by LISREL 7 (Jöreskog & Sörbom 1989).

Substantive Testing of Two Higher-Order Models. The second set of substantive models tested the higher-order structure among the six cognitive factors. In order to specify the two higher-order models, two additional latent factors were included in the model. Because a higher-order structure assumes that the pattern of covariances among a set of lower-order factors is due to the presence of higher-order processes, the residual covariances among the set of lower-order factors are fixed at zero and a directed path from the higher-order latent factor to each of the lower-order factors is specified in their place (Jöreskog & Sörbom 1989).

For the first of the higher-order models, two higher-order factors were specified. The first higher-order factor, termed Planning/Attention, was hypothesized to explain the common relations among the three lower-order factors, Selective Attention, Planned Connections, and Expressive Attention. The second higher-order factor, termed Successive Processing, was hypothesized to explain the common covariation among the three lower-order factors, Word and Sentence Repetition, Speech Rate, and Sequence Repetition. Accordingly, the residual covariances among the three lower-order factors subsumed by the Planning/Attention higher-order factor and the three lower-order factors represented by the Successive Processing higher-order factor were constrained to be zero. Further, all residual covariances between the sets of lower-order factors were also fixed at zero; in their place, a single covariance between the two higher-order factors was estimated (see Jöreskog & Sörbom 1989). This form of restriction assumes that the covariances among the sets of lower-order factors were due to the covariation between the processes represented by the higher-order ability constructs and, further, the residual covariances among the lower-order factors will be orthogonal once the common covariance represented by the higher-order factors is partialled from them. The two higher-order factors had fixed variances of 1.0 in order to identify the factors and establish the scale of measurement at this higher-order level. Covariances were allowed between the Low Achieving factor, the two higher-order factors, and the two outcome factors, Academic Achievement and Word Skills.

The adequacy of the fit of the higher-order structure was tested in the form of
a nested comparison between the less restrictive measurement model and the more restrictive higher-order model. When a model is nested within another model, the difference between the \( \chi^2 \) values associated with each model is a \( \chi^2 \) test of the significance of the difference in fit between the two models. This \( \chi^2 \) test has degrees of freedom equal to the difference in the degrees of freedom associated with each model. A nonsignificant \( \chi^2 \) suggests that the restrictions imposed in the nested model do not significantly reduce the level of fit for the model. Given the parsimony gained and the important theoretical meaning represented by the greater number of restrictions of either higher-order model over the simple measurement model, we considered a significance level at or above .01 to reflect an acceptable loss in fit and a significance level less than .01 to reflect an unacceptable loss in fit.

As mentioned, a second, alternative higher-order model was also specified. This model assumed that a single, general or 'g' factor would be sufficient to explain the covariances among the six lower-order ability factors. The one-factor 'g' model, was evaluated in two ways: both were nested comparisons. The first nested comparison was the same as for the two-factor higher-order model—evaluating the loss in fit between the less restrictive measurement model and the more restrictive 'g' model. The second nested comparison evaluated the difference in fit between the two-factor higher-order model and the one-factor 'g' model. The one-factor 'g' model is nested within the two-factor higher-order model in that four constraints to the two-factor model result in the one-factor model; specifically, the covariance between the two higher-order factors was fixed at 1.0, and the two common covariances with the Low Achieving factor, and the two pair of common covariances with the outcome factors, Academic Achievement and Word Skills, were constrained to be equal. These constraints allowed a test of the significance of the loss in fit by going from a two-factor model to a one-factor 'g' model.

**Directed Relations among the Latent Constructs.** Hypotheses regarding the specification of a final model were generated assuming that the hypothesized model with two higher-order factors would provide the best representation among the six lower-order ability constructs. The final model was specified to evaluate the remaining two hypotheses of the analyses: specifically, to evaluate (a) the external, criterion-related validity of the restricted factorial structure of the cognitive tests and (b) the influence of the low achieving classification on the measures of cognitive skill. In terms of causal precedence, the dummy coded factor, Low Achieving, was placed as the exogenous variable in the model. This decision was based on temporal precedence. That is, the classification was determined during the preceding school year—prior to the administration of the cognitive assessments. The six cognitive factors and their best fitting higher-order form and the two criterion measures of ability were placed next in the causal chain. Interpretationally, relations from the higher-order factors to the six ability measures and the two criterion related measures of ability are interpreted as being
determined by the higher-order factors. Six of the possible 24 directed paths among the latent factors were specified based on previous research and theory. These six paths were (a) Low Achieving to Planning/Attention, (b) Low Achieving to Successive Processing, (c) Planning/Attention to Academic Achievement, (d) Planning/Attention to Word Skills, (e) Successive Processing to Academic Achievement and (f) Successive Processing to Word Skills. The importance of the restrictions placed by these a priori specifications is that (a) the Low Achieving factor would have only indirect relations with the two outcome constructs, Academic Achievement and Word Skills, mediated by its effects on the higher-order factors, (b) the Low Achieving factor would not explain directly any of the residual variance in the lower-order factors, and (c) none of the lower-order factors would have a direct effect on the two outcome constructs.

RESULTS

The correlations among the indicators of each test are presented in Table 1, along with the standard deviations. As can be seen in Table 1, the correlations among the item parcels for a given test were all highly related, typically at the level of the reliabilities reported above. This pattern of covariation suggests that the item parcels are representative groupings of items for each of the constructs measured by the tests.

The Null model evaluated against the measured covariances produced a $\chi^2$ of 1729.9 with 171 degrees of freedom. The rather poor level of fit ($p < .001$) suggests that some relationships among the variables exist. A summary of the $\chi^2$, degrees of freedom and relative fit statistics is presented in Table 2 for each of the models to be presented.

The first substantive model, the Measurement model, was specified as outlined above; however, two estimates were added to this model on the basis of modification indices and their substantive reasonableness. Specifically, an indicator of Planned Connections was allowed to load on the Selective Attention factor, and an indicator of Expressive Attention was allowed to load on the Planned Connections factor. Because the indicators for the Planned Connections factor and the Expressive Attention factor were constrained to be equal for each respective factor, the additional estimates, which were not constrained in any way, are interpreted as partitioning from the respective residual variances of each parcel some variance that is related to the secondary factor. The Measurement model showed excellent levels of fit both statistically, $\chi^2(121) = 128.4, p = .31,$ and practically, $Rho = .993$ (see Table 2).

As mentioned above, two forms of higher-order model were tested. The first higher-order model tested the appropriateness of two higher-order factors in explaining the covariations among the six cognitive factors. This two-factor model, like the measurement model, showed acceptable levels of both statistical fit, $\chi^2(141) = 164.8, p = .08,$ and practical fit, $Rho = .982.$ The decrease in fit between
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SD  | 0.502 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  | 2.0  |

Note: Decimals have been omitted. V1 = Low Achieving; V2-V4 = Selective Attention Parcels 1-3; V5-V6 = Planned Connections parcels 1-2; V7-V8 = Expressive Attention parcels 1-2; V9-V10 = Word and Sentence Repetition parcels 1-3; V11-V13 = Speech Rate parcels 1-2; V14-V15 = Sequence Repetition parcels 1-2; V16 = Academic Achievement indicator; Reading Achievement; V17 = Academic Achievement Indicator; Math Achievement; V18 = Word Skills indicator; Word Identification; V19 = Word Skills indicator; Word Attack. All variables except Low Achieving were standardized to a mean of 0 and a standard deviation of 2.
the measurement model and the two-factor model did not exceed the .01 level and, thus, was acceptable, statistically, $\chi^2(20) = 36.3, p = .014$. Further, given the large number of theoretically derived constraints, the practical parsimony of this model must be underscored. Specifically, this higher-order model represents a 40% reduction in the number of estimated parameters relative to the null model (i.e., from 50 to 30; see Table 2).

In contrast, the second higher-order model, with only a single higher-order ‘g’ factor showed a just acceptable level of statistical fit, $\chi^2(145) = 190.7, p = .01$, and an acceptable level of practical fit, $Rho = .965$ (see Table 2). Unlike the two-factor model, however, the decrease in fit between the Measurement model and the one-factor ‘g’ model was rather significant and, thus, unacceptable, $\chi^2(24) = 62.2, p < .001$. Further, the direct statistical test between the two models showed that the four additional constraints invoked to specify the one-factor ‘g’ model led to significantly worse fit relative to the model with two higher-order factors, $\chi^2(4) = 25.9, p < .001$ (see Table 2). Given this pattern of results, the two-factor higher-order model was deemed the best representation of the higher-order factorial structure inherent in these data.

As mentioned above, the final model evaluated the remaining two goals of the analyses. Initial inspection of the hypothesized directed relations showed that one path was nonsignificant. Specifically, the hypothesized path from Successive Processing to Academic Achievement was nonsignificant and was dropped from the final model. This final model revealed acceptable levels of fit both statistically, $\chi^2(144) = 169.3, p = .07$, and practically, $Rho = .981$ (see Table 2). When compared with the measurement model, the final model showed a level of decrease in fit that, again, did not exceed the .01 level and, thus, was acceptable, $\chi^2(23) = 40.8, p = .012$.

The relations among the measured variables and the latent factors as well as the variance explained in the measured variables by the latent factors in this final
model are presented in Table 3. Of particular importance in Table 3 is that the magnitudes of the loadings for all parcels were rather high, suggesting that each parcel provided substantial information for identifying a given latent factor. The strength of these relations can be seen in the variance explained in each of the measured variables: all were quite substantial (ranging from .58 to .96), suggesting that the final structural model represents a substantial portion of the variance of each of the measured variables.

The relations among the latent factors for the final model are presented in Figure 1; the values listed in Figure 1 are from the LISREL standardized solution (Jöreskog & Sörbom 1989). The figural conventions followed for this model are

**FIGURE 1**
Structural relations among the lower- and higher-order factors of the PASS cognitive abilities battery and the criterion-related outcome factors, Academic Achievement and Word Skills, for 135 third grade students identified as low or normal in reading achievement (Low Achieving).
### TABLE 3
Measurement Model Loadings, Standard Errors, and Explained Variances

<table>
<thead>
<tr>
<th>Parcel</th>
<th>( \lambda )</th>
<th>se</th>
<th>( \theta )</th>
<th>se</th>
<th>( r^2 )</th>
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<td></td>
<td>Selective Attention</td>
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<td>Planned Connections</td>
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<td>Speech Rate</td>
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<td>V12</td>
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<td>V18</td>
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<td>0.106</td>
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Note. \( \lambda \) = the standardized form of the LISREL Lambda loadings, se = standard error of the estimates. \( \theta \) = Theta, the LISREL maximum likelihood estimates of the residual variance of each indicator, \( r^2 \) = variance explained in each indicator by the latent factor. V1 = Low Achieving; V2-V4 = Selective Attention parcels 1-3; V5-V6 = Planned Connections parcels 1-2; V7-V8 = Expressive Attention parcels 1-2; V9-V11 = Word and Sentence Repetition parcels 1-3; V12-V13 = Speech Rate parcels 1-2; V14-15 = Sequence Repetition parcels 1-2; V16 = Academic Achievement indicator, Reading Achievement; V17 = Academic Achievement Indicator, Math Achievement; V18 = Word Skills indicator, Word Identification; V19 = Word Skills indicator, Word Attack. +this parcel was allowed a secondary loading on Selective Attention. *this parcel was allowed a secondary loading on Planning Attention. All two indicator parcels were constrained to be equal.
as follows: The parameter values marked by asterisks and enclosed within the double-arrowed half circles are the residual latent factor variances which were fixed to establish the scale of measurement. In standardized form these values represent unexplained variance (1.0 minus these values would reflect the explained variance). The remaining values listed in Figure 1 represent directed, causal relations which are denoted by the straight, single-arrowed lines, and non-directed, covariance relations which are denoted by the curved, double-arrowed lines. For the directed paths, the estimates are presented parallel to the lines with the standard error of each estimate listed parenthetically immediately adjacent to the estimate. For the covariance relations, the estimates are presented perpendicular to the apex of each curved line with the standard error of each estimate listed parenthetically immediately below the estimate.

Referring to Figure 1, the higher-order factor of Planning/Attention showed approximately equal and moderately sized paths to each of three lower-order factors, specifically, $\beta = .55$ ($se = .11$) for Selective Attention, $\beta = .43$ ($se = .11$) for Planned Connections, and $\beta = .63$ ($se = .13$) for Expressive Attention. Looking at the residual variances of the three respective lower-order factors, 26%, 18%, and 40%, of the variance in these factors was explained by the higher-order Planning/Attention factor. Similarly, the higher-order factor of Successive Processing showed moderate to strong paths to each of three lower-order factors, specifically, $\beta = .52$ ($se = .12$) for Word and Sentence Repetition, $\beta = .88$ ($se = .26$) for Speech Rate, and $\beta = .72$ ($se = .14$) for Sequence Repetition. Looking at the residual variances of the three respective lower-order factors, 27%, 77%, and 51%, of the variance in these factors was explained by the higher-order Successive Processing factor.

The dummy coded factor, Low Achieving, predicted patterns of individual differences in both of the higher-order factors, Planning/Attention ($\beta = -.51$, $se = .10$) and Successive Processing ($\beta = -.31$, $se = .10$). Importantly, the Low Achieving factor did not show any direct relationship with either of the two outcome factors, Academic Achievement and Word Skills, nor with any of the lower-order ability factors. This finding suggests that the individual difference relations associated with the identification of an achievement deficit are mediated by the two higher-order factors of Planning/Attention and Successive Processing. The effects of the Low Achieving factor explained 26% of the variance in Planning/Attention and 10% of the variance in Successive Processing. The residual covariation of .42 between the two higher-order factors, Planning/Attention and Successive Processing, translates into an implied residual correlation of .57.

The outcome factor, Academic Achievement, exhibited only a single directed path from the Planning/Attention higher-order factor which was quite strong ($\beta = .91$, $se = .33$) and explained 83% of the variance in Academic Achievement. For the outcome factor, Word Skills, two directed paths were significant; specifically, the two paths were from Planning/Attention ($\beta = .64$, $se = .18$) and Successive Processing ($\beta = .24$, $se = .10$). These two paths explained 65% of the variance in Word Skills. The residual covariation between Academic Achievement and Word Skills of .14 translates into an implied residual correlation of .42.
DISCUSSION

The final model presented in Figure 1 provides a clear picture of the mediational role that the two higher-order factors of Planning/Attention and Successive Processing play in determining deficits in academic achievement. Of the three hypotheses guiding this investigation, all three were found to be supported by the analyses and in accordance with the theoretical predictions. The first goal was to model the higher-order structure underlying the ability measures of the DN-CAS. The analyses showed that the two factors of Planning/Attention and Successive Processing were superior to a single ‘g’ factor in explaining the pattern of relations among the six lower-order ability constructs. The two-factor structure was both statistically and practically sufficient to explain the pattern of relations among the six ability constructs. This result provides support for three of the components of the PASS (planning, attention, successive, and simultaneous processing) model of intelligence suggested by Naglieri and Das (e.g., 1990). Specifically, the construct, Planning/Attention, encompasses two of the four components suggested by Naglieri and Das and the construct, Successive Processing, represents a third underlying component; however, because simultaneous was not represented in the model, its importance cannot be determined in the context of this study.

The second goal of the analyses, to evaluate the criterion-related validity of the higher-order ability factors, was found to be quite satisfactorily answered: The Planning/Attention construct showed strong patterns of relations with both outcome constructs, Academic Achievement and Word Skills, whereas the Successive Processing construct showed a significant (albeit weaker) relation with the Word Skills construct. Further, these relations were sufficient to explain large proportions of the variance in the two outcome factors (i.e., 83% and 65% of the variance in Academic Achievement and Word Skills, respectively). A significant feature of the model presented in Figure 1 is that none of the lower-order factors had a direct effect on either of the two outcome measures. This finding is also strong validation of the hypothesized relations among the factors represented in the model. Specifically, for each of the lower-order factors, the variance that is not explained by their respective higher-order factor represents reliable variance; however, this reliable variance is not related to performance on the outcome factors. Thus, the shared information among the lower-order factors that is related to the outcome factors, Academic Achievement and Word Skills, is fully captured by the two higher-order factors.

The importance of the underlying higher-order structure was further validated by the pattern of relations found with the Low Achieving construct (the third goal of our analyses). Specifically, the Low Achieving factor showed significant direct effects on only the two higher-order factors of Planning/Attention and Successive Processing; no paths from the Low Achieving factor to the lower-order factors were necessary and, more importantly, no direct paths from the Low Achieving factor to Academic Achievement or Word Skills were necessary. Recall that low achieving children were identified as such based on their deficits in
reading achievement which was assessed the previous year. Further, reading achievement was one of the two indicators for Academic Achievement which was measured at the time of the study. Although some children may improve their reading achievement scores, given this definition of low achieving and all other aspects of the model controlled, a significant negative relationship with Academic Achievement might be expected. However, with the introduction of the two higher-order factors, the deficits in Academic Achievement and Word Skills associated with low reading achievement are mediated completely by the higher-order factors and primarily by the Planning/Attention factor. No direct path from Low Achieving to Academic Achievement was necessary. Thus, the deficits in Academic Achievement associated with the group differences in reading skills represented by the Low Achieving factor were mediated by the deficits in Planning/Attention ability. Similarly, the deficits in Word Skills, as measured by the Woodcock Reading Mastery subtests, are mediated by the deficits in both Planning/Attention ability and Successive Processing ability.

The analyses demonstrated a significant role for the higher-order ability factors in predicting academic performance and mediating deficits in performance. The implications of this pattern of results are that remediation for poor reading achievement should focus primarily on remediating the deficits in Planning and Attentional capabilities of the children and secondarily on their Successive Processing capabilities. In fact, Das and his colleagues (Crawford & Das 1992; Carlson & Das 1992) have developed and applied an approach that addresses the problem of early reading difficulties. The program has two primary goals: (a) the maximization of transfer of learning through teaching principles of global processing and (b) “welding” the processing strategies to specific reading content. The specific processing strategies emphasized are planning and attention and successive processing. The remediation program involves working with children, singly or in small groups, presenting them with global, general, processing tasks as well as reading content-based transfer tasks (i.e., “bridging”). The results of a recent investigation (Carlson & Das 1992) showed substantial gains in word reading and decoding skills for fourth-grade reading disabled children.

Future research exploring the role of simultaneous processing as well as a differentiated representation of Planning and Attention are warranted by the success of the current investigation. Also intriguing, in terms of future analyses, would be an evaluation of the relations between the PASS model of intelligence, with its foundation in Luria’s neurological hypotheses of cognitive processes (e.g., 1980), and the fluid/crystallized model of intelligence advocated by Horn (e.g., Horn 1982, 1986, 1988). Specifically, the relationship between the PASS processes and those of the fluid ability domain appear to have similar theoretical characteristics; an empirical comparison of these two models would prove fruitful in understanding the nature of intellectual abilities.

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NOTES

1. Because the classifications were made by the school district during the previous academic year, the actual achievement test scores were not available to the research team and, thus, could not be included in these analyses. The dichotomous classification does, however, capture meaningful individual differences which, if measured with less restriction of variability would likely lead to even stronger patterns of results.

2. The test battery administered for the current study was a preliminary version of the current DN:CAS. The later revisions contain more tests of planning ability and revised tests of simultaneous processing. Thus, minor differences in this battery and the more recent version exist. As a result of the limitations in the instrument, the current study represents only a subset of the constructs from the PASS model; conclusions regarding the relations among the PASS constructs must be validated using the updated DN:CAS instrument.

3. For each of the nine factors, the factor variances were fixed at 1.0 to establish the scales of measurement. For factors with three indicators, the one fixed parameter was sufficient to identify the factor (Jöreskog & Sörbom 1989); however, for factors with two indicators, an additional fixed parameter was specified in order to identify the factor locally. The additional fixed parameter was in the form of an equality constraint on the pairs of factor, or Lambda, loadings for the two indicator factors (i.e., the constraint of Tau equivalence was placed on the two indicator factors, Jöreskog & Sörbom 1989).

REFERENCES


