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# INDEPENDENT EXAMINATION OF THE FACTOR STRUCTURE OF THE COGNITIVE ASSESSMENT SYSTEM (CAS): FURTHER EVIDENCE CHALLENGING THE CONSTRUCT VALIDITY OF THE CAS

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This study is the first to examine independently the factor structure of the Cognitive Assessment System (CAS; Naglieri & Das, 1997) with a primary dataset not collected by its authors. Participants were 155 students (59 boys, 96 girls), ages 8 to 11 ($M$ = 9.81 years, $SD$ = 0.88), in Grades 3 to 6. Confirmatory factor analysis (CFA) was used to compare the fit provided by the planning, attention, and simultaneous-successive (PASS) model, the theoretical model underlying the CAS, with alternative models of cognitive ability suggested by previous research. Results of this study indicated that the PASS model did *not* provide a better fit to the data than did alternative hierarchical and nonhierarchical models. Not only were the Planning and Attention factors of the PASS model virtually indistinguishable ($r$ = .88), but they demonstrated inadequate specificity for meaningful interpretation. The model reflecting the actual hierarchical structure of the CAS was found to fit the data no better than alternative models based on different theoretical orientations. Of the hierarchical models examined in this study, the best fitting was a hierarchical (PA)SS model with one second-order general factor, psychometric $g$, and three first-order factors reflecting Fluid Intelligence/Visual Processing (Simultaneous), Memory Span (Successive), and Processing Speed (Planning/Attention). In sum, results of this study support Kranzler and Keith's (1999) conclusion that the CAS lacks *structural fidelity*, which means that the CAS does not measure what its authors intended it to measure. Results of this study, therefore, provide further evidence challenging the construct validity of the CAS.

One longstanding criticism of standardized tests of intelligence is that they are not based on sound theory (e.g., Brody, 1992). In recent years, however, advances in theory and statistical methods have led to the development of a number of theory-driven tests, such as the Kaufman Adolescent and Adult Intelligence Test (KAIT; Kaufman & Kaufman, 1993), Woodcock-Johnson Tests of Cognitive Ability-Revised (WJ-R; Woodcock & Johnson, 1989), Universal

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Nonverbal Intelligence Test (UNIT; Bracken & McCallum, 1998), and Cognitive Assessment System (CAS; Naglieri & Das, 1997). Virtually all of these new tests are based on theories of the structure of human cognitive abilities. Theories of the structure of cognitive abilities, such as Carroll's (1993, 1997) three-stratum theory and Cattell-Horn's *Gf-Gc* theory (e.g., Horn, 1994), attempt to explain the organization, or structure, of individual differences in cognitive abilities over the life span. At the present time, the Cattell-Horn-Carroll (CHC) Theory of Cognitive Abilities, which incorporates *Gf-Gc* and three-stratum theory, arguably provides the best description of the structure of human cognitive abilities.[1] This theory is extremely useful to test developers, because it specifies the number and kinds of abilities to assess.[2] Nonetheless, because this theory is essentially a taxonomy, it does not, strictly speaking, provide causal explanations of these abilities or their structure. Hence, structural theories, and the tests that are based upon them, shed little light on the cognitive processing that underlies individual differences in intelligence.

In contrast to the growing number of intelligence tests based on taxonomies of human cognitive abilities, there is a paucity of tests derived from contemporary theories of information processing. One exception to this trend is the CAS (Naglieri & Das, 1997). At present, the CAS is the only standardized test of intelligence based entirely on the planning, attention, and simultaneous-successive (PASS) processes theory of human cognition. Naglieri (1997) stated that the PASS theory was developed from research in the fields of neuropsychology (e.g., Luria, 1966, 1973, 1980) and cognitive science (e.g., Hunt & Lansman, 1986). According to PASS theory, three functional units of the brain are related to the processing of information: (a) attention, which entails the distribution of cognitive resources and effort; (b) information processing, which comprises the use of simultaneous and successive processes to acquire, store, and retrieve information from the surrounding environment; and (c) planning, which involves the formulation, selection, and regulation of plans of action (Das, Naglieri, & Kirby, 1994). According to Naglieri (1997), "the PASS processes are dynamic in nature, respond to the cultural experiences of the individual, are subject to developmental changes, and form an interrelated (correlated) interdependent system" (p. 250). Although conceptualized as related, the PASS processes are seen to be "physiologically and functionally distinct"(Naglieri, Das, & Jarman, 1990).

Naglieri and Das (1997) contended that, because the CAS was developed to assess all four PASS processes, scores on the CAS reflect a broader range of cognitive abilities than do those on traditional tests of intelligence, such as the Wechsler Intelligence Scales for Children-3rd Edition (WISC-III; Wechsler,

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[1]Despite widespread acceptance of the three-stratum theory as the best description of the structure of human cognitive abilities, "the consensus is by no means unanimous, and in any case, scientific truth is not decided by plurality (or even majority) vote" (Sternberg, 1996, p. 11).

[2]Recently, it has come to our attention that Drs. John Horn and John Carroll would like to have "modern *Gf-Gc* theory"—an integration of the Cattell-Horn *Gf-Gc* and three-stratum theories—referred to as the "Cattell-Horn-Carroll Theory of Cognitive Abilities" or "CHC theory" (R. Woodcock, personal communication, July 16, 1999). In this paper, we adopted this new terminology.

1991). They further maintained that the CAS is useful for both determination of eligibility for special education and related services and for effectual differential diagnosis and remediation of cognitive deficits. "Uses of the CAS include diagnosis of the learning strengths and weaknesses; classification (learning disabilities, attention deficit, mental retardation, giftedness); eligibility decisions (meeting state or federal criteria); and consideration of the appropriateness of particular treatment, instructional, or remedial programs" (Naglieri & Das, 1997, p. 9). Given the absence of robust aptitude-treatment interactions in the cognitive domain (e.g., Flanagan, Andrews, & Genshaft, 1997; Reschly, 1997), if Naglieri and Das's claims are substantiated, the CAS would represent a monumental achievement in psychoeducational assessment.

Unfortunately, despite the extensive program of research conducted by Das, Naglieri, and their colleagues on preliminary batteries of PASS tasks (see Das et al., 1994), serious questions surround the construct validity of the CAS. In a recent study, Kranzler and Keith (1999) analyzed the standardization data of the CAS with confirmatory factor analysis (CFA) techniques to address several important and unresolved issues concerning its validity. Results of their study did *not* support the construct validity of the CAS. Although Kranzler and Keith's findings did suggest that the CAS measures the same constructs across its 12-year age span, the model reflecting the implied theoretical structure of the CAS did not fit the data well.[3] The factors underlying the Planning and Attention scales were also found to be virtually indistinguishable, with a mean correlation of .91 across age groups. Moreover, only one of the four factors underlying the PASS scales (viz., Successive) was found to have enough unique variance (i.e., specificity) to be interpreted alone. This finding indicates that the factors underlying the Planning, Attention, and Simultaneous scales overlap to such an extent that ipsative (or intracognitive) analysis of the CAS's PASS scales is inadvisable. Finally, the theoretical model underlying the CAS—the correlated PASS model—did *not* provide the best fit to the data. Of the a priori specified models examined by Kranzler and Keith (1999), the model that provided the best fit to the data was a third-order hierarchical model with one general factor (i.e., psychometric *g*) at the apex of the hierarchy, one intermediate combined Planning/Attention factor, and four first-order factors corresponding to the PASS processes.

Based on their CFA results with the standardization sample, as well as their inspection of the CAS tasks, Kranzler and Keith (1999) concluded that the constructs measured by the CAS are best understood within the CHC theory as processing speed (instead of planning and attention), memory span (rather than successive coding), and a mixture of fluid intelligence and broad visualization (instead of simultaneous coding). Taken as a whole, results of their research indicate that the CAS lacks structural fidelity, a necessary but not sufficient condition for construct validity. This means that the scaled scores

[3]Although PASS theory is not hierarchical, the implied theoretical structure of the CAS is, because the CAS is organized into three levels, with subtest scores being combined to determine the four PASS scale scores and the FS score (i.e., 12 subtests, four correlated first-order factors reflecting the PASS processes, and one second-order general factor).

derived from the CAS do not reflect the theory upon which the test is based. Results of Kranzler and Keith's analyses of the standardization data, therefore, did not support the use of the CAS for differential diagnosis or for planning educational interventions based on the PASS scales (cf. Keith & Kranzler, 1999; Naglieri, 1999a).

The aim of this study was to replicate the results of Kranzler and Keith (1999). Replication of their findings is important for several reasons. First, replication is a requirement of scientific acceptability. If the results of research cannot be replicated, their veracity is questionable. Second, results of any study may be subject to sampling error, even those based on large, randomly selected and nationally stratified standardization samples. Third, and finally, all prior research on the factor structure of preliminary batteries of PASS tasks and the CAS was either conducted by Naglieri, Das, and their colleagues (see Das et al., 1994; Naglieri, 1999b) or by independent researchers using their published data (Carroll, 1995; Kranzler & Keith, 1999; Kranzler & Weng, 1995a).[4] This study is the first to examine *independently* the structure of the CAS with a primary dataset not collected by its authors.

## METHOD

### *Participants*

Participants in this study were 155 students (59 boys, 96 girls), ages 8 to 11 ($M$ = 9.81 years, $SD$ = 0.88), in Grades 3 to 6, from the general education classes of elementary schools in north central Florida and New York City. None of the participants was receiving special education services. In terms of racial/ethnic group composition, the sample included 73 African American, 66 Caucasian, and 12 Asian American children (four participants were of unreported race); 19 participants were of Hispanic descent. The primary home language of 82% of participants was English, with another 10% coming from bilingual homes. All participants were treated in accordance with the "Ethical Principles of Psychologists and Code of Conduct" (American Psychological Association, 1992).

### *Instruments*

The CAS was developed to assess the PASS cognitive processes of children and adolescents (Naglieri & Das, 1997). The standard CAS battery consists of 12 subtests. The PASS processes are reflected in four scales that include the following subtests: *Planning*: Matching Numbers, Planned Codes, and Planned Connections; *Attention*: Expressive Attention, Receptive Attention, and Number Detection; *Simultaneous*: Nonverbal Matrices, Figure Memory, and Verbal-Spatial Relations; and *Successive*: Word Series, Sentence Repetition, and

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[4]Naglieri, Das, and their colleagues published two articles in which CFA was used to examine the factor structure of preliminary batteries of PASS tasks (Naglieri, Braden, & Gottling, 1993; Naglieri, Das, Stevens, & Ledbetter, 1991). Each study, according to the authors, supported the PASS model. Separate independent analyses, however, failed to replicate their results in analyses of the same datasets (Carroll, 1995; Kranzler & Weng, 1995).

either Speech Rate or Sentence Questions, depending on the age of the individual. Those between the age of 5 and 7 years are administered Speech Rate, whereas 8- to 17-year-olds are given Sentence Questions. PASS scale scores are based on an equally weighted composite of the subtests underlying each respective scale. Naglieri and Das (1997) stated that the PASS scale scores can be used to identify cognitive processing strengths and weaknesses. The Full Scale (FS) score is based on an equally weighted aggregate of the PASS subtests and is interpreted as an estimate of overall cognitive functioning. Further information on the PASS theory, organization of the scales, and development of subtests can be found in the *Interpretative Handbook* (Naglieri & Das, 1997, pp. 1–25). Additional information can be found in Das et al. (1994) and in Naglieri (1999b).

### *Procedure*

Consent forms were sent to parents/guardians of all children in Grades 3 to 6 of the general education classes of several elementary schools in north central Florida and New York City. Participants in this study consisted of those who returned signed consent forms. The CAS was administered individually by trained examiners under standardized conditions. Examiners were advanced graduate students in school psychology programs, all of whom had successfully completed a graduate-level seminar and practicum in intellectual assessment.

### *Statistical Analyses*

A series of confirmatory factor analyses (CFAs) was conducted to test the hypotheses in this research. Briefly, a model which embodied the PASS-derived theoretical structure of the CAS was compared to (a) a first-order model in which the Planning and Attention factors were combined (Kranzler & Weng, 1995a, 1995b), testing the hypothesis that they measure the same construct (viz., *Gs*, or Processing Speed; cf. Kranzler & Keith, 1999); (b) a second-order hierarchical model that reflects the actual structure of the CAS; and (c) second- and third-order models that reflect alternative interpretations of the constructs measured by the CAS based on CHC theory (cf. Carroll, 1995; Kranzler & Keith, 1999; Kranzler & Weng, 1995a; McGrew & Flanagan, 1998). The various hierarchical models were also compared to each other.

Because the primary focus of this research was to compare competing models, we focused on fit statistics that are useful for that purpose. In particular, the change in chi-square ($\Delta\chi^2$), along with degrees of freedom and associated probability, is useful for a statistical comparison of competing, nested models. If two models are "nested" (i.e., one model is a more constrained version of another), then the difference between their $\chi^2$s can be used to determine whether one model fits significantly better than another. We used the change in $\chi^2$ ($\Delta\chi^2$) as our primary method of comparing competing models. In the $\chi^2$ test, the null hypothesis is that the data conform to the simpler, or more parsimonious, of the two models compared. The alternative hypothesis is that the data conform to the more complex model. Failure to reject the null hypothesis indicates that the more complex model is not necessary. In CFA, parsimony is determined empirically by comparing the *df* of each model, with greater parsimony corresponding to more *df*. Thus, when the $\Delta\chi^2$ is not significant, the nested model with the larger *df* is preferred; when the $\Delta\chi^2$ is statistically significant, the nested model with the smaller *df* is preferred.

In addition, the Akaike Information Criterion (AIC), which can be used to compare non-nested, competing models, was used for that purpose. When comparing models, lower values of the AIC indicate better fit. These two fit indices were the primary criteria by which we compared models, supplemented by the Parsimony Goodness of Fit Index (PGFI). When comparing models, larger PGFI values indicate better fit. Two "stand-alone" fit indices are also reported: the Root Mean Square Error of Approximation (RMSEA) and the Comparative Fit Index (CFI). These fit indices were not used for model comparisons, however. An RMSEA below .05 suggests a good fit of the model to the data (Hu & Bentler, 1999), as does a CFI above .95. See Hoyle and Panter (1995) or Tanaka (1993) for additional discussion of assessing model fit.

The Amos computer program was used to conduct the CFAs reported in this research. Maximum-likelihood estimation of age-corrected raw scores was used for all analyses.[5] The specific procedures for each step in the analyses are described in more detail along with the results of the analyses (for further information on this method of CFA, see Keith, 1997).

## RESULTS

Table 1 displays the correlations among the age-corrected CAS subtests. Also shown are the standard deviations for each test. The means of these age-corrected raw scores were all zero. Planned Connections scores were reversed so that positive scores represent above-average performance.

### *Nonhierarchical Models*

Figure 1 shows the initial model testing the structure of the CAS. The correlated PASS model, which reflects the theoretical structure of the CAS, specifies that each subtest measures one, and only one, of the four PASS processes. To aid in interpretation, the model includes both the CAS factor names (e.g., Planning, Attention) and the alternative factor names employed by Kranzler and Keith (1999; Perceptual Speed, Rate-of-Test-Taking, etc.). As shown in the figure (and in Table 2), the model derived from the PASS theory provided a marginal fit to the data: the RMSEA was above .05, and the CFI was below .95. Again, however, our primary interest was in comparing competing models. Examination of more detailed indices of fit (i.e., standardized residuals and modification indices) suggested that freeing the correlation between the unique and error variances of the Planned Codes and the Sentence Repetition tests would lead to a significant improvement in the fit of the PASS model; this "correlated error" may reflect a narrow memory component shared by these

[5]Age-corrected raw scores were used because they provided a better fit to the initial PASS model than did standard scores. To correct for age, raw scores were regressed on age in months, with the residuals representing age-corrected raw scores. This method should also provide more complete age correction than standard scores.

Table 1
*Correlations among CAS Subtests and Standard Deviations*

| Subtest | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Matching Numbers | 1.00 | | | | | | | | | | | |
| 2. Planned Codes | 0.20 | 1.00 | | | | | | | | | | |
| 3. Planned Connections | 0.40 | 0.28 | 1.00 | | | | | | | | | |
| 4. Expressive Attention | 0.24 | 0.07 | 0.12 | 1.00 | | | | | | | | |
| 5. Number Detection | 0.38 | 0.34 | 0.47 | 0.26 | 1.00 | | | | | | | |
| 6. Receptive Attention | 0.33 | 0.36 | 0.36 | 0.32 | 0.49 | 1.00 | | | | | | |
| 7. Nonverbal Matrices | 0.29 | 0.11 | 0.37 | 0.21 | 0.29 | 0.27 | 1.00 | | | | | |
| 8. Verbal Spatial Relations | 0.21 | 0.05 | 0.21 | 0.23 | 0.33 | 0.26 | 0.39 | 1.00 | | | | |
| 9. Figure Memory | 0.34 | 0.09 | 0.37 | 0.18 | 0.39 | 0.24 | 0.55 | 0.41 | 1.00 | | | |
| 10. Word Series | 0.13 | 0.07 | 0.18 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.09 | 1.00 | | |
| 11. Sentence Repetition | 0.09 | 0.33 | 0.14 | 0.26 | 0.14 | 0.15 | 0.10 | 0.14 | 0.23 | 0.40 | 1.00 | |
| 12. Sentence Questions | 0.17 | 0.15 | 0.20 | 0.18 | 0.10 | 0.15 | 0.16 | 0.25 | 0.18 | 0.38 | 0.36 | 1.00 |
| *SD* | 3.13 | 16.26 | 73.99 | 10.35 | 13.03 | 9.19 | 4.86 | 3.45 | 4.33 | 2.19 | 2.36 | 2.96 |

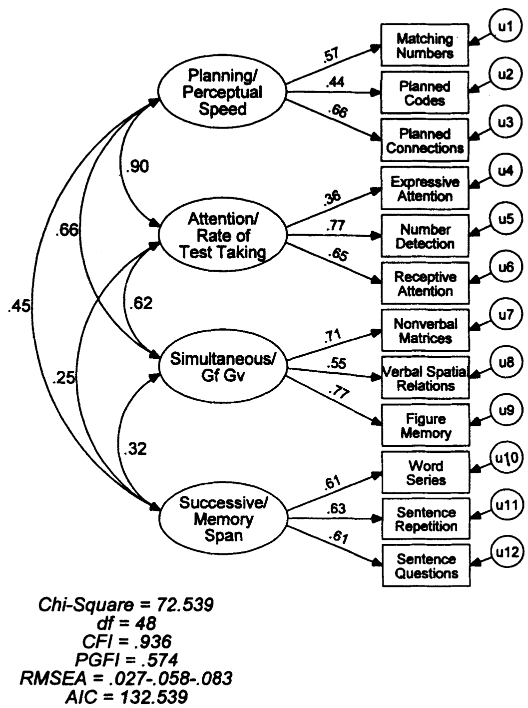


**FIGURE 1. The nonhierarchical PASS model of the CAS.**

two tests. This minor change in the model resulted in a significant improvement in its fit to the data; as shown in Table 2, $\Delta\chi^2$ decreased by 11.197, a statistically significant improvement in fit ($p < .001$). With this change, this revised PASS model also provided a good fit to the data using conventional criteria. Given the improved fit, we included this modification in all subsequent models and used this revised PASS model for comparison to alternative models. As in previous research, however, the correlation between the Planning and Attention factors was very high, .88.

Table 2
*Comparison of Models of the CAS*

| Models | $\chi^2$ (*df*) | $\Delta\chi^2$ (*df*)[a] | *p* | CFI | PGFI | RMSEA | AIC |
|---|---|---|---|---|---|---|---|
| PASS model | 72.539 (48) | | | .936 | .574 | .058 | 132.539 |
| PASS model, revised | 61.342 (47) | 11.197 (1)[b] | <.001 | .963 | .567 | .045 | 123.342 |
| (PA)SS model | 65.687 (50) | 4.345 (3) | .227 | .959 | .600 | .045 | 121.687 |
| Hierarchical PASS model | 64.333 (49) | 2.991 (2) | .224 | .960 | .590 | .045 | 122.333 |
| Hierarchical CHC model | 62.921 (48) | 1.579 (1) | .209 | .961 | .578 | .045 | 122.921 |
| | | 1.412 (1)[b] | .235 | | | | |
| Hierarchical (PA)SS (second-order CHC) model[c] | 65.687 (50) | 4.345 (3) | .227 | .959 | .600 | .045 | 121.687 |

[a]Compared to the PASS revised model.
[b]Compared to the preceding model.
[c]This model is equivalent statistically to the first-order (PA)SS model.

Given that previous research has suggested the difficulty in distinguishing Planning from Attention factors (Carroll, 1995; Kranzler & Keith, 1999; Kranzler & Weng, 1995a, 1995b), we tested the equivalence of these two factors by combining them in a (PA)SS model. For this model, the six tests designed to measure planning and attention processes were used as indicators of a single Planning/Attention (or *Gs*, Processing Speed) factor. As shown in the table, the (PA)SS model resulted in an increase in $\Delta\chi^2$ ($\Delta\chi^2 = 4.345$ [3], $p = .227$). That increase, however, was not statistically significant, thus supporting the more parsimonious (PA)SS model over the PASS model. Results of comparison of these nonhierarchical models, therefore, support treating the Planning and Attention tests on the CAS as measures of the same basic underlying construct, rather than separate constructs.

### *Hierarchical Models*

Naglieri and Das (1997) stated that "the CAS is organized into *three levels*: the Full Scale; the Planning, Attention, Simultaneous, and Successive (PASS) cognitive processing Scales; and the subtests" (p. 7, emphasis added). Because the CAS consists of three levels of scores, its *actual* structure is hierarchical (cf. Keith & Kranzler, 1999; Naglieri, 1999b). The hierarchical factor model reflecting the actual structure of the CAS is shown in Figure 2. This model is more parsimonious than the PASS model and is also nested with it. As shown in Table

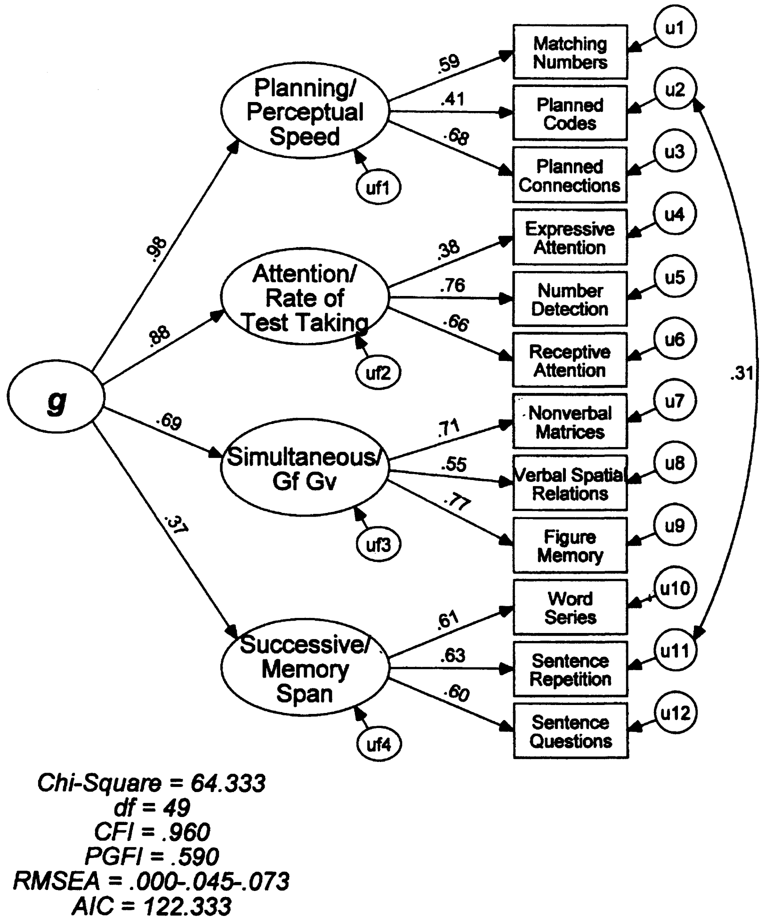


**FIGURE 2. The second-order hierarchical PASS model of the CAS.**

2, this second-order hierarchical model (or hierarchical PASS model) had an equivalent fit with the PASS model, as judged by the nonsignificant $\Delta\chi^2$; because the hierarchical PASS model is more parsimonious, it is supported over the PASS model.

Figure 3 shows the third-order model based on CHC theory supported in Kranzler and Keith (1999). This model is more parsimonious than the PASS model. Using the $\Delta\chi^2$ criterion, this model was equivalent to the PASS model (see Table 2) and thus would be supported over it. This model may also be compared with the hierarchical PASS model. The third-order CHC model is less parsimonious than the hierarchical PASS model, and thus the nonsignificant $\Delta\chi^2$ shown in Table 2 supports the hierarchical PASS model over the third-order CHC model.

The final hierarchical model that we examined is a hierarchical version of the (PA)SS model, with three first-order factors and one second-order psychometric *g* factor (i.e., [PA]SS + *g*). This model, which Kranzler and Weng (1995a) found to provide the best description of the factor structure of a preliminary

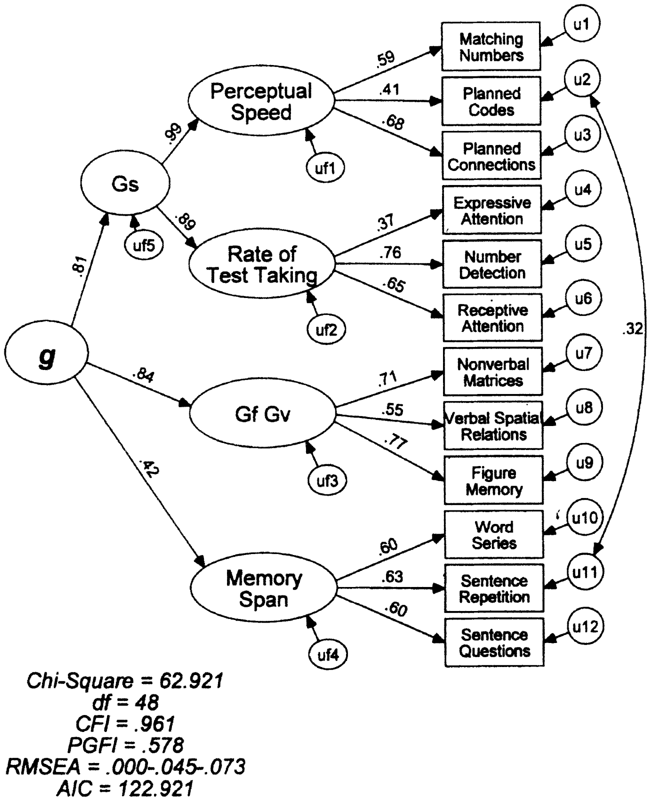


**FIGURE 3. The third-order hierarchical CHC model of the CAS.**

battery of PASS tasks (cf. Naglieri et al., 1991), is statistically indistinguishable from the (PA)SS model.[6] This model is not nested with the other hierarchical models but may be compared to them via the AIC. As shown in Table 2, this hierarchical (PA)SS model provided the best fit of all of the hierarchical models (this model was also supported by the PGFI). The model is shown in Figure 4. It is worth noting that this model is *theoretically* equivalent to the third-order hierarchical model based on the CHC theory, without the specification of the narrow abilities under *Gs*; the model is thus also labeled as a second-order CHC model.

Table 3 shows the amount of variance for the PASS (or CHC) factors that may be considered *specific* variance for each of the three hierarchical models tested in this research.[7] These factor specificities provide information on the

[6]The (PA)SS and the hierarchical (PA)SS models are statistically indistinguishable because the hierarchical portion of the model (i.e., the second-order factor loadings) is "just-identified." In other words, the three factor correlations from the (PA)SS model were "used up" in estimating the three second-order factor loadings for the hierarchical (PA)SS model, and no degrees of freedom were gained.

[7]It may seem disconcerting to discuss model-dependent specificities, but all estimates of specificities are model dependent; other methods of estimating specific variance simply do not make their models obvious.

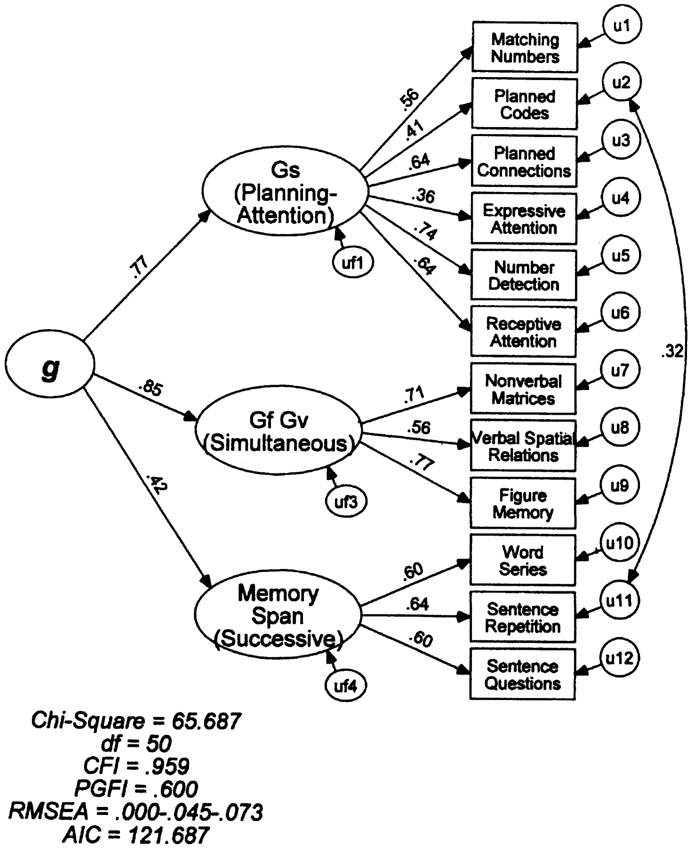


**FIGURE 4. Hierarchical (PA)SS, or second-order CHC, model of the CAS. This model is also consistent with CHC theory and is theoretically equivalent to the model in Figure 3.**

Table 3
*Specificity of CAS Factors for Different Hierarchical Models*

| PASS Scale/Construct | Second-Order PASS Model | Third-Order CHC Model | Hierarchical (PA)SS/Second-Order CHC Model |
|---|---|---|---|
| *Gs*/Planning-Attention | N/A | .347 | .404 |
| Planning/Perceptual Speed | .030 | .029 | N/A |
| Attention/Rate-of-Test-Taking | .218 | .201 | N/A |
| Simultaneous/*Gf-Gv* | .526 | .298 | .279 |
| Successive/Memory Span | .864 | .822 | .826 |

Note.—The second-order PASS model reflects the actual structure of the CAS; N/A = Not applicable.

degree to which the composite scores on the CAS (viz., Planning, Attention, Simultaneous, and Successive scale scores) may be interpreted in isolation. One "rule of thumb" for the interpretation of individual scores on intelligence tests is that there should be (a) more reliable unique variance than error variance and (b) the unique variance should exceed 25% (see Kaufman, 1990, pp. 254-255). As shown in Table 3, no matter which model is used, the score representing the Planning (Perceptual Speed) factor has virtually no unique (specific) variance, suggesting that the Planning scale should not be interpreted in isolation. The specificity of the Attention factor is somewhat higher, but less than 25% criterion for ample specificity across the models. For all models, in contrast, the Successive (Memory Span) factor had considerable unique variance, indicating that scores on the Successive Scale can be interpreted in isolation. Specificities for the Simultaneous or *Gf-Gv* factor were much more model-dependent than for the other factors. For the hierarchical (PA)SS model, however, the model that provided the best fit to the data, this factor showed ample specificity. Finally, the *Gs* factor for this model had considerable unique variance, suggesting that a combined Planning/Attention scale also could be interpreted alone.

## DISCUSSION

The aim of this study was to replicate the results of Kranzler and Keith's (1999) reanalyses of the CAS standardization data. According to Kranzler and Keith's CFA results, (a) the theoretical model underlying the CAS (i.e., the correlated PASS model) did not provide the best description of its factor structure, (b) a model reflecting the actual structure of the CAS did not provide a good fit to the data, (c) most of the PASS scales have insufficient unique variance to be interpreted in isolation, and (d) the structure of the CAS is better explained from an alternative theoretical perspective (i.e., CHC theory). Kranzler and Keith (1999) also proposed an alternative explanation of the CAS factor structure within the framework of CHC theory. Specifically, a third-order hierarchical model with *g* at the apex, a second-order Speed of Processing (*Gs*) factor, and four first-order factors (viz., Perceptual Speed [P], Rate-of-Test-Taking [R9], Fluid Intelligence/Visual Processing [*Gf/Gv*], and Memory Span [MS]), was identified as the best-fitting model and most parsimonious explanation of the CAS standardization data. Although supported by data from the CAS standardization sample, this model needs to be replicated and tested against new data before it can be accepted as a satisfactory description of the CAS factor structure and indeed a better description than the PASS model.

In light of the findings of the extant research on the structural fidelity of the CAS, the present study compared competing models of the underlying factor structure of this instrument, including the one specified by Kranzler and Keith (1999). Moreover, this study was the first to examine *independently* the internal structure of the CAS with a primary dataset obtained by researchers other than the tests' authors (Das & Naglieri, 1997) and their colleagues. As an initial analysis, we used CFA to examine the fit provided by the correlated PASS model purported to underlie the CAS (Naglieri & Das, 1997). This model provided a marginal fit to the data; although with a minor revision, it provided a good fit. It is important to note, however, that this minor revision was not suggested by PASS theory. In addition, examination of the factor solution of this model indicated that the Planning and Attention factors are highly correlated (i.e., .88). This finding is consistent with previous research, which revealed that the factors underlying the Planning and Attention scales of the CAS tasks are virtually indistinguishable (Kranzler & Keith, 1999).

The high correlation found between the Planning and Attention factors of the PASS model in this study, as well as in previous research with preliminary batteries of PASS tasks and the CAS standardization sample (Carroll, 1995; Kranzler & Keith, 1999; Kranzler & Weng, 1995a; Naglieri et al., 1991), supported an alternative explanation of the factor structure of the CAS in which the Planning/Attention factors are combined. We therefore examined the fit provided by a nonhierarchical (PA)SS model. This model provided an equivalent fit and was more parsimonious than the PASS model. Hence, of the nonhierarchical models examined in this study, the (PA)SS model provided the most satisfactory explanation of the factor structure of the CAS.

In addition to examining these nonhierarchical models, we examined a number of hierarchical models. The first model was based on the *actual* structure of the CAS. This model is a second-order hierarchical PASS model (i.e., PASS + *g*), with *g* at the apex (reflecting the FS score of the CAS) and four first-order factors corresponding to the PASS scaled scores (cf. Keith & Kranzler, 1999; Kranzler & Keith, 1999; Naglieri, 1999). This hierarchical PASS model fit the data as well as the PASS model and is a more parsimonious explanation of the CAS factor structure. The PASS + *g* hierarchical model, therefore, is preferable to the PASS model, because the most parsimonious explanation of any given data should be preferred over a more complex explanation when all else is equal.

In addition to examining the fit provided by the actual CAS structure, we also examined the hierarchical CHC model identified by Kranzler and Keith (1999). This hierarchical model consisted of a third-order *g* factor, a second-order Processing Speed (or *Gs*) factor, and four first-order factors (viz., Perceptual Speed, Rate-of-Test-Taking, Fluid Intelligence/Visual Processing, and Memory Span). The Planning and Attention factors were subsumed by the intermediate *Gs* factor in this model. Results for this model were also mixed, however. The hierarchical CHC model was superior to the PASS model, but not as good as the hierarchical PASS model using the $\Delta\chi^2$ criterion used to compare competing, nested models.

Given the high correlation between the Planning and Attention factors, the hierarchical nature of the actual CAS structure, and our finding that the (PA)SS model provided the best fit to the data of all the nonhierarchical models, we also examined a hierarchical (PA)SS, or second-order CHC, model. Specifically, this model consisted of a second-order *g* factor and three first-order factors, including *Gs* (all the Planning and Attention tests), *Gf/Gv* (all the Simultaneous tests), and Memory Span (all the Successive tests). This model provided the best fit to the data of all the hierarchical models evaluated in this study. Moreover, this model is theoretically equivalent to the third-order hierarchical model specified in the current study and in Kranzler and Keith (1999). Results of this study are also consistent with those of Kranzler and Weng (1995a, 1995b), who found that the (PA)SS + *g* hierarchical model provided the best description of the structure of a preliminary battery of PASS tasks (Naglieri et al., 1991).

This study also supported Kranzler and Keith's (1999) finding that the first-order factors underlying the CAS do not have ample unique variance (i.e., specificity) to be interpreted in isolation. If the scores on the CAS are to be used for differential diagnosis and treatment planning, then all four PASS scales must measure distinct constructs. Results of this study, as well as those of Kranzler and Keith (1999), however, do not support the ipsative (or intracognitive) analysis of the CAS. Because the Planning and Attention factors overlap to such a considerable extent, the independent interpretation of the scales representing these factors is ill advised. The Successive and Simultaneous factors and a combined Planning/Attention factor, in contrast, were found to have enough unique variance to support their independent interpretation.

*Potential Limitations*

A potential limitation of this study concerns the sample characteristics. We did not test our hypotheses across the entire age span assessed by the CAS. Instead, we were limited to a sample of regular education students in Grades 3 to 6. Nonetheless, we believe the results of our study are generalizable to other age groups, because the factor structure of the CAS does not differ significantly across the age groups in the CAS (see Kranzler & Keith, 1999).

In addition to this potential limitation, because participants in this research consisted of a diverse group of regular education students in terms of race/ethnicity, age, and gender, critics might argue that the proportion of students in our sample in each of these categories differed from the standardization sample of the CAS. Research on test bias for over 25 years, however, has clearly shown that the constructs measured by intelligence tests are the same across groups of English-speaking children born and raised in the United States (e.g., Jensen, 1980). Moreover, at the current time there are no data to suggest that the CAS is biased (i.e., measures different constructs) across groups. Thus, the demographic characteristics of our sample do not limit the generalizability of our results on the factor structure of the CAS.

In addition, the factor analyses conducted by Naglieri, Das, and their colleagues "always have been very limited, with no more than perhaps 10 or 12 tests in any one study, in such a way that it is difficult to define or cross-identify the factors found" (Carroll, 1995, p. 400). Despite the fact that our results support the conclusions reached in other independent research on the CAS, results of this study are similarly limited. Although the findings reported in this research support interpretation of the CAS from the perspective of the CHC theory rather than the PASS theory, with the limited number of tests included on the CAS it is not possible to conduct strong, unequivocal comparisons of these two orientations (Kranzler & Keith, 1999). A joint CFA of the CAS and another, better understood measure of cognitive ability, especially one that measures the constructs from CHC theory (e.g., the WJ-R), would address this gap in the literature and shed further light on the constructs measured by the CAS. At the present time, however, the results of such a joint CFA have yet to be published.

Table 4
*Comparison of the Results of Research on the Factor Structure of the Cognitive Assessment System*

| Naglieri, Das, & Colleagues | Kranzler & Keith (1999) | Present Study |
|---|---|---|
| Nonhierarchical model | Hierarchical model | Hierarchical model |
| No *g* in PASS model | Substantial *g* | Substantial *g* |
| P & A separate constructs | P & A same construct | P & A same construct |
| P & A separate processes | P & A = *Gs* | P & A = *Gs* |
| CAS does not measure *Gs* | Two narrow *Gs* abilities | One broad *Gs* ability |
| Adequate specificity | Inadequate specificity | Inadequate specificity |

Note.— *g* = Psychometric *g*; P = Planning; A = Attention; *Gs* = Processing speed.

## CONCLUSION

As summarized in Table 4, results of this study support the substantive conclusions reached by Kranzler and Keith (1999) and contradict those by Naglieri, Das, and their colleagues. We found that the theoretical model (i.e., correlated PASS model) purported by Naglieri and Das (1997) to underlie the CAS did not provide the best fit to the data; nor did it represent the most parsimonious explanation of this instrument's underlying factor structure. Instead, results of this study suggest that the processes underlying the CAS are explained, in part, by a general factor of cognitive ability (or psychometric *g*) and three first-order factors (viz., Processing Speed, Fluid Intelligence/Visual Processing, Memory Span). Moreover, examination of the uniqueness of the first-order factors underlying the CAS suggests that, of the CAS scales, only the Successive scale has enough unique variance to be interpreted alone.

Taken as a whole, our analyses and interpretations, as well as those of previous researchers, suggest that the CAS lacks structural fidelity, a necessary but not sufficient condition for construct validity (see Keith & Kranzler, 1999; Kranzler & Keith, 1999). The absence of structural fidelity indicates that the CAS does not measure the constructs it was intended to measure. These results underscore the need for further revision of PASS theory, the tests developed to measure the PASS constructs, or perhaps both. Reconsideration of the constructs measured by the CAS is necessary to allow practitioners to draw clear and useful conclusions from the CAS scores. In the absence of psychometrically sound (i.e., valid) measures of the focal constructs specified by the PASS theory, the practical utility of the CAS is limited, at best. Interpretations that can be drawn from the CAS test scores in terms of the test's underlying theory are therefore suspect.

Results of this study further suggest that the CHC theory provides a more convincing framework for understanding the cognitive constructs that underlie the CAS. Practitioners are advised to interpret the scores on the CAS with caution and use the CHC framework, rather than PASS theory, as a basis for drawing inferences about test performance on the CAS. The alternative CHC explanation of the structure of the CAS is supported on both rational (Flanagan, McGrew, & Ortiz, 2000; McGrew & Flanagan, 1998) and empirical

(Carroll, 1995; Keith & Kranzler, 1999; Kranzler & Keith, 1999; Kranzler & Weng, 1995a) grounds, as required by contemporary definitions of test validation (see Messick, 1989). Until compelling evidence suggests otherwise, we recommend that practitioners interpret the CAS tests as measures of dimensions of ability that have been researched and validated and are within the framework of the CHC theory.

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