Interpreting Intelligence Tests from Contemporary 
Gf-Gc Theory: Joint Confirmatory Factor Analysis 
of the WJ-R and KAIT in a Non-White Sample

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In the present study, the correlations of test scores between the Woodcock-Johnson-Revised (WJ-R) and the Kaufman Adolescent and Adult Intelligence Test (KAIT) were factor analyzed in order to test the replicability of the contemporary Horn-Cattell Gf-Gc model in a non-White sample and to gain a more complete understanding of the factorial structure of the KAIT. The empirically supported Gf-Gc theoretical model underlying the WJ-R was used as the criterion against which to evaluate the cognitive abilities that are measured by the KAIT. Participants were 114 6th-, 7th-, and 8th-grade students ranging in age from 10 years, 11 months to 15 years, 11 months. Confirmatory factor analyses were used to evaluate and compare eight a priori factor models and one post-hoc factor model. A Gf-Gc nine-factor model was the most plausible a priori model fit of the WJ-R/KAIT data, a finding that extends the replicability of the Gf-Gc model to a non-White sample. The factorial structure of the KAIT put forward by its authors (i.e., a two-factor Gf-Gc model) was not supported. It appears that the KAIT measures Glr or long-term retrieval (associative memory) and Gsm or short-term memory (memory span) in addition to fluid and crystallized abilities. These results provide support for use of the Gf-Gc theory in a non-White sample and interpreting the KAIT from contemporary Gf-Gc theory rather than a two-factor model. © 1998 Society for the Study of School Psychology. Published by Elsevier Science Ltd

Keywords: Gf-Gc theory, Intelligence, Multicultural, KAIT, WJ-R.

This past decade has seen a marked increase in instruments and techniques for assessing intellectual functioning, such as the Kaufman Adolescent and Adult Intelligence Test (KAIT; Kaufman & Kaufman, 1993) and the Woodcock-Johnson-Revised, Tests of Cognitive Ability (WJ-R COG; Woodcock & Johnson, 1989), as well as new and revised theories of intelligence (see Flanagan, Genshaft, & Harrison, 1997, for an overview). Despite this recent
surge of intelligence batteries, practitioners rely predominantly on the
Wechsler Scales (Wechsler, 1981, 1989, 1991) to assess cognitive function-
ing (Harrison, Kaufman, Hickman, & Kaufman, 1988; Stinnett, Havey, &
oehler-Stinnett, 1994; Wilson & Reschly, 1996). Therefore, most prac-
titioners use intelligence batteries that conceptualize intelligence as a gen-
eral ability (i.e., a full scale IQ) under which either dichotomous abilities
(i.e., verbal and performance) or four different abilities (i.e., verbal com-
prehension, perceptual organization, freedom from distractibility, and pro-
cessing speed) are subsumed.

Although much progress has occurred in the development and revision
of theories of intelligence in recent years, the *psychometric approach* is the
most widely used and empirically supported (Neisser et al., 1996). Within
the psychometric approach, differences of opinion exist on the conceptual-
ization of intelligence as a single (i.e., *g*) or multidimensional construct.
For example, using the norm data of the Wechsler Intelligence Scale for
Children-Third Edition (WISC-III; Wechsler, 1991), Macmann and Bar-
net’s (1994) analyses supported a single *g* model while Keith’s (1994) anal-
yses supported a hierarchical model (i.e., four first-order factors and a sec-
ond-order *g* factor). The differences between the Macmann-Barnett and
Keith WISC-III models reflect a lack of consensus on the structure of intel-
ligence, even when the same data are factor analyzed by different research-
ers. In addition, when the Wechsler subtests were joint factor analyzed with
a broad range of cognitive ability tests, more than four factors were found to
underlie this instrument (Woodcock, 1990), suggesting that psychometric
conceptualizations of intelligence need to be based on studies that include
a broader range of tests than those comprising a single test battery (see
also Carroll, 1993a). These type of studies are best conceived from existing
psychometric theories of intelligence that are supported by structural evi-
dence as well as nonfactor analytic evidence.

Reviews of the extant factor analytic research over the past 50 to 60 years
on intelligence (e.g., Carroll, 1983, 1989, 1993a, 1997; Gustafson, 1984, 1988;
Horn, 1988, 1991, 1994; Lohman, 1989; Snow, 1986) suggest that the
scientific evidence does not support either a single general intelligence
model or dichotomous models (e.g., verbal/nonverbal, fluid/crystallized,
simultaneous/sequential). These reviews have tended to converge on a
model of multiple human cognitive abilities. In particular, Horn and Catt-
tell’s *Gf-Gc* theory (Cattell, 1941; Horn, 1985, 1988, 1991, 1994) and Car-
roll’s (1993a, 1997) hierarchical three-stratum theory are two of the most
prominent *empirically derived* theories of multiple cognitive abilities to date.

Building on the work of Cattell, Horn’s program of *Gf-Gc* research has
identified nine broad abilities including Fluid Reasoning (*Gf*), Accultura-
tion Knowledge or Crystallized Intelligence (*Gc*), Short-Term Apprehen-
sion-Retention (*Gsm*), Visual Processing (*Gv*), Auditory Processing (*Ga*),
Fluency of Retrieval from Long-Term Storage (*Glr*), Processing Speed
Flanagan and McGrew

(Gs), Correct Decision Speed (CDS), and Quantitative Knowledge (Gq) (Horn, 1994). In addition to these abilities, Woodcock (1993, in press) has provided preliminary support for a broad Reading-Writing factor (Grw). Similarly, Carroll’s (1993a) seminal work has identified eight broad cognitive ability factors (i.e., Fluid Intelligence, Crystallized Intelligence, General Memory and Learning, Broad Visual Perception, Broad Auditory Perception, Broad Retrieval Ability, Broad Cognitive Speediness, Processing Speed/Reaction Time Decision Speed). The most salient differences between the theoretical frameworks of Carroll and Horn are that Carroll’s model includes a higher-order general intelligence factor (g) (referred to as a stratum III ability) and does not specify a quantitative ability factor (Gq).

Both Horn’s and Carroll’s models include a set of correlated second-order broad cognitive factors that Carroll refers to as stratum II abilities which subsume a set of correlated first-order factors that are referred to as narrow, stratum I abilities. For example, the broad Ge factor represents an individual’s range and depth of knowledge of a culture, including the ability to communicate and reason with previously learned procedures. The narrow abilities that comprise this factor may include tests of language development, lexical knowledge, listening ability and general information to name a few. Despite the differences between Horn’s and Carroll’s models, the Gf-Ge factors identified by these scholars are very similar. Ten Gf-Ge broad cognitive abilities are described in Table 1.

In addition to this factor analytic (structural) evidence for the Gf-Ge conception of intelligence, support for this model of multiple abilities is found also in the form of (a) developmental evidence—changes in abilities across age; (b) neurocognitive evidence—relationship to indicators of physiological and neurological functioning; (c) achievement evidence—predictions of academic performance and occupational achievement; and (d) heritability evidence—relationships among persons who are related biologically to differing degrees (see Carroll, 1993a; Horn, 1994; Horn & Noll, 1997, for a review). Moreover, studies have shown that the Gf-Ge structure of intelligence is invariant across the lifespan (e.g., Bickley, Keith, & Wolfe, 1995) and across ethnic and cultural groups (e.g., Carroll, 1993a), although a limited number of studies have been conducted with regard to the latter.

In general, Gf-Ge models are based on a more thorough network of validity evidence than other contemporary multidimensional ability models of intelligence. In a review and comparison of Gf-Ge theory, Gardner’s Theory of Multiple Intelligences and Sternberg’s Triarchic Theory, Messick (1992) criticized the latter two theories for their selective attention to certain forms of validity evidence and the offering of new sets of rules for evaluating this evidence. Messick concluded that of the contemporary multiple human cognitive ability theories, Gf-Ge theory has the strongest network of validity evidence, and, should be used as a framework from which to evaluate the
Table 1
Ten Gf-Gc Broad Cognitive Factor Definitions

<table>
<thead>
<tr>
<th>Gf-Gc Factor</th>
<th>Gf-Gc Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid Reasoning</td>
<td>Gf</td>
<td>Ability to reason, form concepts, and problem solve, using novel information and/or procedures</td>
</tr>
<tr>
<td>Crystallized Intell.</td>
<td>Gc</td>
<td>Measures an individual’s breadth and depth of general knowledge and knowledge of a culture, including verbal communication and reasoning with previously learned procedures</td>
</tr>
<tr>
<td>Visual Processing</td>
<td>Gv</td>
<td>Ability to analyze and synthesize visual information</td>
</tr>
<tr>
<td>Auditory Processing</td>
<td>Ga</td>
<td>Ability to analyze and synthesize auditory information</td>
</tr>
<tr>
<td>Processing Speed</td>
<td>Gs</td>
<td>Ability to quickly perform automatic cognitive tasks, particularly when under pressure to maintain focused concentration</td>
</tr>
<tr>
<td>Short-Term Memory</td>
<td>Gsm</td>
<td>Ability to temporarily hold information in immediate awareness and then use it within a few seconds</td>
</tr>
<tr>
<td>Long-Term Retrieval</td>
<td>Glr</td>
<td>Ability to store information and retrieve it later through association</td>
</tr>
<tr>
<td>Quantitative Knowledge</td>
<td>Gq</td>
<td>Ability to comprehend quantitative concepts and relationships and to manipulate numerical symbols</td>
</tr>
<tr>
<td>Correct Decision Speed</td>
<td>CDS</td>
<td>Quickness in providing correct answers to a variety of moderately difficult problems in comprehension, reasoning, and problem solving</td>
</tr>
<tr>
<td>Reading-Writing</td>
<td>Grw</td>
<td>Ability to read and write, including facility in basic reading and writing skills and the skills necessary for comprehension/expression (currently not well defined in the literature)</td>
</tr>
</tbody>
</table>

Theories of Gardner and Sternberg. Given the breadth of empirical support for the Gf-Gc structure of intelligence, models based on Gf-Gc theory (i.e., the Horn-Cattell and Carroll models) appear to provide some of the most useful frameworks for designing and evaluating intelligence tests (Carroll, 1997; Flanagan & McGrew, 1995a, 1997; McGrew, 1997; Woodcock, 1990).

**IMPORTANCE OF JOINT FACTOR ANALYSES**

The construct validity of several major intelligence test batteries has been questioned recently by researchers (see Flanagan & McGrew, 1995b; McGrew & Flanagan, 1998 for a summary). One “problem” with the construct validity evidence typically reported in intelligence test manuals is that the factor analytic evidence usually is based on only the subtests that are included in the test battery (e.g., the factor analyses reported in the
WISC-III manual are restricted to the 13 WISC-III subtests). The inclusion of only the subtests within a test battery in factor analytic studies likely results in an insufficient breadth of cognitive measures (or markers) to allow for a complete understanding of the general, broad, and narrow abilities that are measured by the battery (Carroll, 1993b; Keith & Witta, 1997; Woodcock, 1990). If factor analytic studies are to be used to identify the cognitive constructs measured by a test battery, then studies should be designed to represent the full range of known human cognitive abilities (e.g., eight or nine broad Gf-Gc abilities identified by Carroll and Horn). In addition, these studies should include at least two or three relatively pure markers (i.e., strong or moderate measures but not mixed measures) for each of the abilities represented so that the abilities measured by the individual cognitive tests can be identified clearly (Woodcock, 1990).

Among our major intelligence test batteries, the Woodcock-Johnson Psycho-Educational Battery-Revised (WJ-R; Woodcock & Johnson, 1989) appears to measure the greatest range of human cognitive abilities. An eight-factor Gf-Gc model provided the best overall fit of the WJ-R data when compared to a single factor (first-order g) model, a Verbal/Nonverbal model, and a hierarchical g model (McGrew, Werder, & Woodcock, 1991). The results of these analyses revealed that 16 of the WJ-R tests can be used as relatively pure markers for eight cognitive abilities (i.e., Gf, Gc, Gq, Gsm, Ghr, Ga, Gv, Gs) in joint factor analyses with other intelligence test batteries to infer common Gf-Gc factor concepts across test batteries.

Woodcock (1990) and McGhee (1993) used the Gf-Gc model underlying the WJ-R as a validated framework against which to evaluate the cognitive abilities measured by most of the major intelligence test batteries. Using the 16 WJ-R tests as markers for eight Gf-Gc factors, Woodcock (1990) conducted a series of joint confirmatory factor analyses of the Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1985), the Stanford-Binet Intelligence Scale: Fourth Edition (SB:FE; Thorndike, Hagen, & Sattler, 1986) and the Wechsler Scales, while McGhee (1993) conducted confirmatory factor analyses of the DAS and Detroit Tests of Learning Aptitude-3 (DTLA-3; Hammill & Bryant, 1991). When a criterion of two or three markers is used to identify Gf-Gc factors, it is evident from these analyses that most intelligence batteries include only 3 or 4 Gf-Gc factors that can be interpreted confidently (see Table 2). Also, some intelligence test batteries contain only one relatively pure measure of one or more Gf-Gc factors (e.g., Digit Span is the only indicator of Gsm in the Wechsler Scales), a situation that limits generalizations about an individual’s performance in a Gf-Gc cognitive domain without additional supporting data.

Inspection of Table 2 also shows that, with the exception of the WJ-R, intelligence test batteries have few or no tests that measure Long-Term Retrieval (Ghr), Processing Speed (Gs), Auditory Processing (Ga), and
<table>
<thead>
<tr>
<th>GfGe Factor</th>
<th>WJ-R</th>
<th>Wechsler’s</th>
<th>SB-IV</th>
<th>DAS²</th>
<th>KABC²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long-Term Retrieval (Gb)</td>
<td>Memory for Names</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Vis-Aud Learning</td>
<td>—</td>
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<tr>
<td>Delayed Recall-MN</td>
<td>—</td>
<td>—</td>
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<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Delayed Recall-VAL</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Short-Term Memory (Gsm)</td>
<td>Memory for Words</td>
<td>Digit Span</td>
<td>Memory for Digits</td>
<td>Recall of Designs</td>
<td>Number Recall</td>
</tr>
<tr>
<td>Memory for Sent. (Gc*)</td>
<td>Memory for Digits</td>
<td>Memory for Objects</td>
<td>Recall of Designs</td>
<td>Number Recall</td>
<td></td>
</tr>
<tr>
<td>Numbers Reversed (Gf*)</td>
<td>Bead Memory (Gv*)</td>
<td>—</td>
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</tr>
<tr>
<td>Processing Speed (Gs)</td>
<td>Visual Matching</td>
<td>Coding/Digit</td>
<td>Coding/Digit</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Cross Out</td>
<td>Symbol Search</td>
<td>Symbol Search</td>
<td>—</td>
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</tr>
<tr>
<td>Auditory Processing (Ga)</td>
<td>Incomplete Words</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sound Blending</td>
<td>Sound Patterns (Gf*)</td>
<td>—</td>
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</tr>
<tr>
<td>Visual Processing (Ge)</td>
<td>Visual Closure</td>
<td>Block Design</td>
<td>Pattern Analysis</td>
<td>Pattern Construction</td>
<td>Triangles</td>
</tr>
<tr>
<td>Picture Recognition</td>
<td>Object Assembly</td>
<td>Copying</td>
<td>Copying</td>
<td>Pattern Construction</td>
<td>Gestalt Closure</td>
</tr>
<tr>
<td>Spatial Relations (Gf*)</td>
<td>Mazes</td>
<td>Paper Fold. (Gq*)</td>
<td>Mat. Analog. (Gf*)</td>
<td>Triangles</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Picture Comp (Gc*)</td>
<td>—</td>
<td>—</td>
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<tr>
<td></td>
<td>Picture Arrang (Gc*)</td>
<td>—</td>
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</tr>
<tr>
<td>Comprehension-Knowledge ($G_c$)</td>
<td>Picture Vocabulary</td>
<td>Information Similarities</td>
<td>Vocabulary Verbal Relations</td>
<td>Word Definitions Similarities</td>
<td>Faces &amp; Places Riddles</td>
</tr>
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</tr>
<tr>
<td>Oral Vocabulary</td>
<td>Listening Comp.</td>
<td>Vocabulary Comprehension</td>
<td>Comprehension Absurdities</td>
<td></td>
<td>Expressive Voc.</td>
</tr>
</tbody>
</table>

| Fluid Reasoning ($G_f$)         | Analysis-Synthesis | Matrices                 | Matrices                  | Seq-Quant Reason ($G_q$)    |                     |
|                                 | Concept Formation  |                         |                           |                             |                     |

| Quantitative Ability ($G_q$)    | Calculation        | Arithmetic               | Quantitative Number Series | —                           | Arithmetic          |
|                                 | Applied Problems   |                         | Equation Building         |                             |                     |


*Secondary factor loading.  
*Only a subset of DAS and K-ABC subtests were joint factor analyzed by McGhee (1993) and Woodcock (1999), respectively. Therefore, only the subtests that were included in these analyses are reported in this table. The $G_f$-$G_c$ factor classifications of all DAS and K-ABC subtests following a logical task analysis and expert consensus are reported in McGrew (1997) and McGrew and Flanagan (1998).
Fluid Intelligence (Gf). The omission of these tests on cognitive batteries is an important one since many of these abilities have been shown to predict significantly reading, mathematics, and writing achievement across the life-span (e.g., McGrew, 1993; McGrew, Flanagan, Keith, & Vanderwood, 1997; McGrew & Hessler, 1995; McGrew & Knopik, 1993). Depending on the instrument used, most current intelligence tests appear to measure mainly Visual Processing (Gv), Crystallized Intelligence (Gc), and Short-Term Memory (Gsm). The results and implications of these and other joint factor analyses have been summarized by McGrew (1994, 1997) and McGrew and Flanagan (1998).

THE THEORETICAL FOUNDATION OF THE KAIT

The KAIT is a new intelligence test battery that was developed from Horn and Cattell’s (1966, 1967) original dichotomous Gf-Gc conception of cognitive functioning (i.e., a two-factor, fluid-crystallized model) (Kaufman & Kaufman, 1993). The KAIT appears to operationalize an older theoretical conception of intelligence and, therefore, it is difficult to interpret from a contemporary Gf-Gc framework. Studies reported in the KAIT manual provide support for the Gf-Gc dichotomous structure underlying this instrument (Kaufman & Kaufman, 1993), which the authors interpreted as Fluid (Gf) and Crystallized (Gc) ability. However, this validity evidence must be viewed cautiously, since the KAIT was not correlated or factor analyzed with validated measures of fluid intelligence (Flanagan, 1995; Flanagan, Alfonso, & Flanagan, 1994; Keith, 1995). Rather, the KAIT joint factor analysis studies only included additional tests from the Wechsler batteries (Kaufman & Kaufman, 1993) that do not contain strong measures of fluid intelligence (Carroll, 1993a; McGrew & Flanagan, 1996; Woodcock, 1990). Factor analyses that include a full range of cognitive abilities believed to be necessary to perform the various KAIT tasks, such as strong measures of Gf, are needed to test hypotheses regarding the Gf-Gc model underlying this instrument. Through this type of analysis it will be possible to develop a more complete understanding of the factorial structure of the KAIT (Flanagan, 1995; Flanagan et al., 1994; Keith, 1995).

Purpose

The purpose of the present study is to factor analyze the correlations of test scores from the WJ-R and KAIT in order to test the replicability of the contemporary Horn-Cattell Gf-Gc model in a non-White sample and to gain a more complete understanding of the Gf-Gc factorial structure of the KAIT. The present factor analyses will include a broad range of cognitive abilities, including two strong measures of Gf. Therefore, this study is the first to examine directly the construct validity of the KAIT’s Fluid scale in
particular. Given the increasing interest and scientific value in interpreting intelligence tests from broad conceptual and theoretical frameworks that are grounded in contemporary theory and research (e.g., Carroll, 1993a, 1993b, 1997; Elliott, 1990; Flanagan & McGrew, 1995a, 1995b; Keith & Witta, 1997; McGrew, 1994, 1997; McGrew & Flanagan, 1998; Woodcock, 1990, in press), results of this analysis may provide preliminary support for the *Gf*-*Gc* structure of intelligence in a non-white sample and the interpretation of the KAIT from contemporary *Gf*-*Gc* theory.

**METHOD**

**Participants**

Participants were 114 students who attended the 6th, 7th, and 8th grades at a predominantly lower-class parochial school (total enrollment approximately 600 students) in an inner-city community located in the Northeast. These students were selected randomly, from the available pool of returned parent permission forms (i.e., 132/188 or 70% of returned forms), to participate in the study. An attempt was made to equalize gender as well as the number of students from each grade. The final sample consisted of 114 students, 56 males and 58 females. An approximately equal number of these students were from the 6th (*n* = 40) and 7th (*n* = 43) grades whereas students from the 8th grade were slightly underrepresented (*n* = 31). Eighty-five students were African American and 29 students were Hispanic. The sample ranged in age from 10 years, 11 months to 15 years, 11 months (*M* = 149 months; *SD* = 15 months). An examination of the means and standard deviations presented in Table 3 demonstrates that the present sample performed within the average range of ability on 26 of the 27 cognitive tests administered.

**Procedure**

The following tests were administered to all participants in counterbalanced order to control for systematic sources of bias (e.g., response set): Tests 1 to 14 of the WJ-R COG (Extended Scale), tests 22 (Letter-Word Identification) and 32 (Reading Vocabulary) of the WJ-R Tests of Achievement (WJ-R ACH; Woodcock & Johnson, 1989, 1990), tests 1 to 10 of the KAIT (Extended Battery), and the Object Assembly (OA) subtest of the Wechsler Intelligence Scale for Children-Third Edition (Wechsler, 1991). Previous studies have demonstrated that the tests that comprise the Visual Processing (*Gv*) Cluster of the WJ-R COG are generally moderate measures of this construct (e.g., Woodcock, 1990). These same studies demonstrated that OA is generally a stronger measure of *Gv* than either of the two *Gv* markers included in the WJ-R COG battery. Therefore, OA was adminis-
Table 3
Descriptive Statistics for WJ-R, KAIT, and WISC-III Tests (N = 114)

<table>
<thead>
<tr>
<th>Test</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WJ-R</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Memory for Names</td>
<td>99.7</td>
<td>13.3</td>
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<tr>
<td>Memory for Sentences</td>
<td>98.4</td>
<td>13.1</td>
</tr>
<tr>
<td>Visual Matching</td>
<td>97.1</td>
<td>15.8</td>
</tr>
<tr>
<td>Incomplete Words</td>
<td>90.1</td>
<td>15.5</td>
</tr>
<tr>
<td>Visual Closure</td>
<td>96.2</td>
<td>17.7</td>
</tr>
<tr>
<td>Picture Vocabulary</td>
<td>95.6</td>
<td>13.5</td>
</tr>
<tr>
<td>Analysis-Synthesis</td>
<td>97.4</td>
<td>14.6</td>
</tr>
<tr>
<td>Visual-Auditory Learning</td>
<td>100.7</td>
<td>14.6</td>
</tr>
<tr>
<td>Memory for Words</td>
<td>97.4</td>
<td>13.9</td>
</tr>
<tr>
<td>Cross Out</td>
<td>96.3</td>
<td>15.2</td>
</tr>
<tr>
<td>Sound Blending</td>
<td>88.0</td>
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</tr>
<tr>
<td>Picture Recognition</td>
<td>100.0</td>
<td>19.0</td>
</tr>
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<td>Oral Vocabulary</td>
<td>98.0</td>
<td>13.4</td>
</tr>
<tr>
<td>Concept Formation</td>
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<tr>
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<td>102.2</td>
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<tr>
<td>Reading Vocabulary</td>
<td>99.2</td>
<td>12.2</td>
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<td><strong>KAIT</strong></td>
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<td></td>
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<tr>
<td>Definitions</td>
<td>9.3</td>
<td>2.7</td>
</tr>
<tr>
<td>Rebus Learning</td>
<td>9.9</td>
<td>2.9</td>
</tr>
<tr>
<td>Logical Steps</td>
<td>9.4</td>
<td>2.7</td>
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<tr>
<td>Auditory Comprehension</td>
<td>9.2</td>
<td>2.4</td>
</tr>
<tr>
<td>Mystery Codes</td>
<td>9.7</td>
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</tr>
<tr>
<td>Double Meanings</td>
<td>9.1</td>
<td>2.6</td>
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<tr>
<td>Rebus Delayed Recall</td>
<td>9.8</td>
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<tr>
<td>Auditory Delayed Recall</td>
<td>9.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Memory for Block Designs</td>
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<tr>
<td>Famous Faces</td>
<td>9.8</td>
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<tr>
<td><strong>WISC-III</strong></td>
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</tr>
<tr>
<td>Object Assembly</td>
<td>8.9</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Note. WJ-R = Woodcock-Johnson-Revised; KAIT = Kaufman Adolescent and Adult Intelligence Test; WISC-III = Wechsler Intelligence Scale for Children-Third Edition. KAIT and WISC-III test scores are on a scale with a mean of 10 and standard deviation of 3. The WJ-R test scores are on a scale with a mean of 100 and a standard deviation of 15.

Instruments

The WJ-R COG is appropriate for use with individuals aged 24 months through 95+ years. It contains 21 tests of cognitive ability that are divided...
into standard and supplemental batteries. The standard battery contains seven tests, one measure for each of the seven Gf-Gc factors (i.e., Gf, Gc, Gv, Ga, Gs, Gsm, Glr) assessed by the WJ-R COG. The supplemental battery contains 14 tests. Of these, the first seven (i.e., tests 8–14) provide complementary measures of the above cognitive factors and constitute the additional tests that are necessary to calculate the seven Gf-Gc Cognitive Ability Clusters. The remaining seven tests on the WJ-R COG supplemental battery (i.e., tests 15–21) provide mixed measures of Gf-Gc abilities and may be administered to derive additional information about an individual’s cognitive strengths and weaknesses. Tests 1 to 14 were used in the present study. The WJ-R COG has strong psychometric properties including standardization, reliability, and validity (see WJ-R Technical Manual; McGrew et al., 1991) as well as good support for the use of its tests as markers for eight Gf-Gc factors (McGhee, 1993; McGhee & Lieberman, 1993; McGhee, Buckhalt, & Phillips, 1994; McGrew et al., 1991; Woodcock, 1990, in press; Ysseldyke, 1990).

The KAIT is appropriate for use with individuals aged 11 years through 85+ years. It is comprised of three intelligence scales called Crystallized, Fluid, and Composite Intelligence that have a mean of 100 and a standard deviation of 15. The KAIT’s Core Battery contains three Fluid subtests (Logical Steps, Mystery Codes, Rebus Learning) and three Crystallized subtests (Definitions, Double Meanings, Auditory Comprehension) that have a mean of 10 and standard deviation of 3. The KAIT also has an Expanded Battery that includes the six subtests from the Core Battery plus four other subtests, one crystallized subtest (Famous Faces), one fluid subtest (Memory for Block Designs), and two memory subtests (Rebus Delayed Recall and Auditory Delayed Recall). For detailed descriptions of the KAIT subtests and their underlying cognitive abilities, the reader is referred to Flanagan, Genshaft, and Boyce (in press), Kaufman and Horn (1996), Kaufman and Kaufman (1993, 1997), Keith (1997), and McGrew (1997). The psychometric properties of the KAIT regarding standardization and reliability are good (Flanagan, 1995; Kaufman & Kaufman, 1993; Keith, 1995). In addition, the validity evidence reported in the KAIT manual (Kaufman & Kaufman, 1993) and by independent researchers (Keith, 1997) provide initial support for the theoretical model underlying this instrument. The 10 subtests that comprise the KAIT Expanded Battery were used in the present study.

Data Analysis

The latent variable analytic method of confirmatory factor analysis (LISREL; Jöreskog & Sörbom, 1993) was used to evaluate and compare eight a priori factor models and one post-hoc factor model.1 Confirmatory factor meth-

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1 The correlation matrix can be obtained by contacting either of the authors.
ods, which are a subset of structural equation modeling (SEM) procedures, were used as they are particularly well suited to the formulation and evaluation of theoretical models (e.g., Gf-Gc theory), make important contributions to theory development and construct validation, and permit the study of the empirical characteristics of measurement instruments (e.g., WJ-R, KAIT) (Keith, 1988; Raykov & Widaman, 1995). The application of this methodology has increased rapidly in the behavioral, social and educational sciences in recent years. For example, these methods have been used frequently to address important theoretical questions about the structure of and relations between constructs in behavioral domains (e.g., Bensen & Bandalos, 1992; Byrne, 1989), and have proven to be very useful for evaluating the constructs that underlie intelligence tests (e.g., Keith, 1988, 1997).

Model Specification. Model specification was based on a review of prior research and theory, with the resulting models representing different variations of the nine-factor model presented in Figure 1. As per standard path analytic form, the circles in Figure 1 represent the latent factors, the rectangles the measures or manifest variables (i.e., the tests), the arrows from the circles to the rectangles the factor loadings, and the single-headed arrows on the rectangles the residuals (combination of error and unique variance) for the tests. The double-headed arrows between the ovals that represent the latent factor correlations have been omitted for readability purposes.

A priori Expanded Contemporary Gf-Gc (WJ-R) Nine-Factor Model. Four models were specified that were based on contemporary Gf-Gc theory, the theory that served as the foundation for the WJ-R cognitive battery. The Expanded Contemporary Gf-Gc (WJ-R) Nine-Factor Model (Figure 1) is described in detail since all other models can be understood by making changes to this model. The term expanded indicates that this model includes a reading factor and separate short-term auditory and visual memory factors, factors not frequently included in most prior WJ-R Gf-Gc research.

The specification of the Crystallized Intelligence (Gc), Fluid Intelligence (Gf), Memory Span (MS-Gsm), Associative Memory (MA-Gb), Phonetic Coding (PC-Ga), and Perceptual Speed (PS-Gs) factors is consistent with the extant WJ-R/ Gf-Gc research literature. The factor labels used in Figure 1 (and throughout the results and discussion sections of this manuscript) are consistent with the stratum I narrow factor definitions provided by Carroll (1993a). These factor labels differ from the Gf-Gc factor labels commonly used to describe the WJ-R factors (i.e., Gf, Gc, Gb, Gs, etc.) as the interpretation of prior WJ-R confirmatory studies tended to confound Carroll’s stratum II broad Gf-Gc factors with stratum I narrow factors (McGrew, 1997).

The difference between the order of a factor and the stratum to which it is assigned is an important and often overlooked distinction in factor analytic
studies. According to Carroll (1993a), “The order of a factor refers to the purely operational level of analysis at which it is found. The stratum of a factor would refer to an absolute measure of its degree of generality over the domain of cognitive abilities” (p. 577). Therefore, the order at which a factor has been operationally isolated in a given factor analysis is indepen-
dent of the stratum to which it is assigned. In most factor-analytic studies however, the order of a factor and the stratum to which it is assigned are the same (Carroll, 1993a). Given that an understanding of the degree of generality that is represented by a battery of cognitive tests is critical to the test interpretation process, hereinafter factors will be discussed and interpreted according to strata rather than order. (For a complete list of Gf-Gc stratum I and II ability definitions see Carroll, 1993a.)

Using the work of McGrew (1997) as a guide, we evaluated the breadth of each factor specified in the current study against the definitions provided by Carroll, and used either stratum II broad Gf-Gc factor notations (e.g., Gv) or the stratum I factor labels followed by their respective stratum II labels (e.g., Closure Speed or CS-Gv), depending on the diversity of tests represented by each factor. For example, two factors in Figure 1 (i.e., Gc and Gf) retain the broad Gf-Gc factor labels because task analysis of diversity of indicators defining these two factors (McGrew, 1997) shows that these are broader factors more consistent with Carroll’s stratum II Gf-Gc factors. Some factors that have been labeled as stratum II Gf-Gc factors in previous studies (e.g., the WJ-R Visual Matching and Cross Out based factor labeled of Gs in Woodcock, 1990) have been given a stratum I label in this study because the indicators that define these factors are measures of only one stratum I or narrow factor (e.g., Perceptual Speed). In order for a factor to retain a stratum II broad Gf-Gc factor label, it must be broad; that is, comprised of two or more different stratum I narrow abilities. Table 4 contains the names and definitions of the stratum I factors that were identified in the present study. (For a complete list of stratum I ability definitions, see Carroll, 1993a and McGrew, 1997.)

A consensus-based classification of the KAIT tests (McGrew, 1997), as well as Kaufman and Kaufman’s (1993) recommended interpretation, suggested that the KAIT Logical Steps and Mystery Codes tests should join the WJ-R Analysis-Synthesis and Concept Formation tests as indicators of a broad Gf factor, and, the KAIT Double Meanings, Definitions, Famous Faces, and Auditory Comprehension tests would be clear indicators of Gc. The KAIT Rebus Learning and Delayed Recall-Rebus Learning Tests are close analogues of the WJ-R Visual-Auditory Learning test (Kaufman & Kaufman, 1993), and thus were included under the Associative Memory (MA-G/lb) factor. The KAIT does not contain auditory processing or speeded tests that would be indicators of the Phonetic Coding (PC-Ga) or Perceptual Speed (PS-Gs) factors included in the model represented in Figure 1.

The specification of the Visual Memory (MV-G/m) and Closure Speed (CS-Gv) factors is at variance from most of the prior WJ-R research where the Visual Closure and Picture Recognition tests typically formed a weak Gv factor. Task analysis of the WJ-R Picture Recognition test (McGrew, 1997) and the research of McGhee and colleagues (e.g., McGhee & Lieber-
Table 4

Definitions of the Gf-Gc Stratum I Abilities Identified in the Present Study

Fluid Intelligence/Reasoning (Gf)

General Sequential Reasoning (RG): Ability to start with stated rules, premises, or conditions, and to engage in one or more steps to reach a solution to a problem

Induction (I): Ability to discover the underlying characteristics (e.g., rule, concept, process, trend, class membership) that governs a problem or a set of materials

Crystallized Intelligence/Knowledge (Gc)

Language Development (LD): General development, or the understanding of words, sentences, and paragraphs (not requiring reading), in spoken native language skills

Lexical Knowledge (VL): Extent of vocabulary that can be understood in terms of correct word meanings

Listening Ability (LS): Ability to listen and comprehend oral communications

General (verbal) Information (K0): Range of general knowledge

Information about Culture (K2): Range of cultural knowledge (e.g., music, art)

Short-Term Memory (Gsm)

Memory Span (MS): Ability to attend to and immediately recall temporally ordered elements in the correct order after a single presentation

Visual Memory (MV): Ability to form and store a mental representation or image of a visual stimulus and then recognize or recall it later

Visual Intelligence/Processing (Gv)

Closure Speed (CS): Ability to quickly combine disconnected, vague, or partially obscured visual stimuli or patterns into a meaningful whole, without knowing in advance what the pattern is

Auditory Intelligence/Processing (Ga)

Phonetic Coding (PC): Ability to process speech sounds, as in identifying, isolating, and blending sounds; phonological awareness

Long-Term Retrieval (Glr)

Associative Memory (MA): Ability to recall one part of a previously learned but unrelated pair of items when the other part is presented (i.e., paired-associative learning)

Processing Speed (Gs)

Perceptual Speed (P): Ability to rapidly search for and compare visual symbols presented side-by-side or separated in a visual field

Note: The definitions in this table were provided by Carroll (1993a) and adapted by McGrew (1997). See Carroll (1993a) for an extensive list of the 69 stratum I abilities he has identified and defined in his research.
of correlated error terms between the original and delayed versions of these two pairs of tests (represented by the arrows running to and from the rectangles for each respective pair of tests). The model presented in Figure 1 (as well as all other models) were specified with oblique (correlated) factors, a specification consistent with our current understanding of the intercorrelations between cognitive abilities (Carroll, 1993a).

**Other a priori expanded contemporary or contemporary Gf-Gc (WJ-R) models.** To test Carroll’s (1993a) inclusion of reading factors under the broad Gc factor, the indicators of the Reading factor (RD/V-Grw) were combined with the Gc tests to define a broader Gc factor in the Expanded Contemporary Gf-Gc (WJ-R) Eight-Factor model. The Contemporary Gf-Gc (WJ-R) Seven-Factor model differed from the model summarized in Figure 1 by the combining of the Gc and Reading (RD/V-Grw) factors into a single broad Gc factor, and the combining of the Visual Memory (MV-Gsm) and Closure Speed (CS-Gv) factors into a single broad Gv factor. A second variation of this model (Contemporary Gf-Gc (WJ-R) Eight-Factor) was similar to the seven-factor version with the exception of the separate Gc and Reading (RD/V-Grw) factors being maintained.

The four other a priori models reflected older conceptualizations of the structure of intelligence. The Gf-Gc (KAIT) Five-Factor model was specified to reflect Kaufman and Kaufman’s (1993) Gf-Gc dichotomous KAIT structure. The Gc factor was a combination of the Gc and Reading (RD/V-Grw) factors in Figure 1. The Gf factor included all the tests of the Gf, Associative Memory (MA-Glr), Visual Memory (MV-Gv), and Closure Speed (CS-Gv) factors in the model in Figure 1. Since the KAIT does not include measures of short-term auditory memory (Memory Span), auditory processing (Phonetic Coding), or speed of processing (Perceptual Speed), the WJ-R tests of these factors were left as the lone indicators of these three factors (it was felt that this was a fairer treatment of the Kaufman and Kaufman KAIT model, in contrast to trying to force all of the WJ-R tests of these abilities into two broad Gf-Gc factors). A second version of this model (Gf-Gc (KAIT) Six-Factor) only differed in the specification of separate Gc and Reading (RD/V-Grw) factors.

To investigate a simple Gf-Gc dichotomous model, a two-factor model (Original Gf-Gc) was specified that included a Gc factor (the combination of the Gc and Reading factors from the model in Figure 1) and a very broad Gf factor (all other KAIT and WJ-R tests). Finally, a one-factor model consistent with Spearman’s single g factor model (Spearman g) included all tests as indicators of a single general intelligence factor.

**Post-Hoc/Readjusted Models.** Inspection of the LISREL modification indexes (MI) and expected parameter change values (EPCV) from the four best fitting a priori models suggested ways to improve the fit of these models.
The high MI values identified model parameters that, if added to the model, would improve the overall model fit by reducing the size of the chi-square value. The EPCV estimates predicted the size and sign of parameters that might be added to the models. Parameters were considered for addition to models only if their respective MI values were among the highest MI values reported, and if the EPCV estimates were positive. Four additional KAIT indicator-factor parameters were added to the four best fitting models, namely the two Contemporary Gf-Gc (WJ-R) and two Expanded Contemporary Gf-Gc (WJ-R) models (such additions would not have appreciably improved the fit of the four poorest fitting models to make such changes worthwhile, see Results section).

These additions were the most consistent “suggestions” made by the LISREL program across model results, and all made substantive sense. The requirement to listen and retain the stories presented in the KAIT Auditory Comprehension test, a process that requires immediate auditory apprehension and memory, was consistent with the nature of the Memory Span (MS-Gsm) factor, and thus, this test was specified to be an indicator of this factor. The ability to draw upon previously acquired knowledge to help answer the KAIT Auditory Comprehension-Delayed Recall test items was also consistent with the specification of this test as an indicator of Gc. Finally, the specification of the KAIT Definitions and Double Meanings tests as indicators of the Reading (RD/V-Grw) factor is consistent with expert-based task analysis (McGrew, 1997) and the test author’s own interpretative material for these two tests (Kaufman & Kaufman, 1993).

The presence of a number of relatively large MI values for the TD or theta delta matrix (a finding that can be interpreted as reflecting the presence of correlated error between two variables or the presence of an unspecified factor) (see Rubio & Gillespie, 1995) suggested that a 10-factor model should be considered. This model (Post-Hoc Expanded Contemporary Gf-Gc /WJ-R/) was identical to the model in Figure 1 (including the four KAIT indicator-factor parameter additions previously described), with the exception of the decomposition of the Gf factor into separate Induction (I-Gf) and General Sequential Reasoning (RG-Gf) factors, the two key first-order factors that define a broad stratum II Gf ability (Carroll, 1993a). An additional parameter that was not included in the other models, was a correlated error term between KAIT Definitions and WJ-R Letter-Word Identification tests.

Model Estimation and Evaluation. Model specification was followed by the estimation of model parameters and fit statistics with the iterative maximum likelihood fitting function in the LISREL computer program (PC/DOS-based Version 8.02; Jöreskog & Sörbom, 1993). Multiple fit statistics were used to evaluate the models (Loehlin, 1987; Tanaka, 1993).

The chi-square statistic for different models can be used to compare differ-
ent models, with lower chi-square values suggesting a relatively “better” fit to the data. However, the chi-square statistic is known to be unduly sensitive to sample size, and thus, other fit statistics are needed to compare competing models. Standardized root mean square residual (rmr) values below .10 are considered to reflect a good fit (Cole, 1987). Conversely, the Goodness-of-fit index (GFI) and Adjusted Goodness-of-fit index (AGFI), which are analogous to the multiple and adjusted multiple correlation in regression analyses (Tanaka, 1993), provide normed values between 0 and 1, with 1.0 being a perfect fit. The Parsimonious Goodness-of-fit index (PGFI) is from a family of parsimony fit indices that penalize models that have a large number of parameters in favor of simpler models (Tanaka, 1993). Given that the current study was comparing alternative models, comparisons between the size of the respective model fit statistics, and not the absolute value of the fit statistics, was of most importance (Tanaka, 1993). Because post hoc readjustment procedures can capitalize on chance associations in sample data, the fit statistics from the post-hoc models must be viewed with caution until the models are cross-validated in an independent sample.

In all but the simplest Spearman g and Original Gf-Gc models, the test loadings on factors defined by only two tests were very high (.90s) and often showed “Heywood cases” (one of the test factor loadings exceeding a value of 1.0). Such Heywood cases are common with samples less than 100 (the current sample was 114) and when only two indicators are used per factor (Loehlin, 1987; Long, 1983). To deal with this problem, a researcher can either constrain or fix the 1.0+ factor loading parameters to 1.0, or, as was the choice in the current study, the factor loadings for the two-indicator factors can be constrained to be equal.

RESULTS

The goodness-of-fit statistics in Table 5 reveal a clear difference between the fit of the older (i.e., Spearman g, Original Gf-Gc, Gf-Gc [KAIT] Five-Factor, Gf-Gc [KAIT] Six-Factor) and contemporary (the four contemporary and expanded contemporary Gf-Gc [WJ-R]) a priori models. These results suggest that older models of intelligence that posit a single general intelligence factor or that maintain a focus on the Gf-Gc dichotomy (even when additional Gsm, Ga, and Gs factors are included), are relatively poor representations of the multidimensionality of the structure of the combined KAIT and WJ-R tests in this study. Therefore, these four models where dropped from additional consideration. From these data, it is clear that some variation of the more complex contemporary or expanded contemporary Gf-Gc models is necessary to fully account for the complexity of human intelligence in the current sample.

Although there are some differences between the fit statistics for the a priori contemporary Gf-Gc (WJ-R) and two expanded contemporary Gf-Gc...
Table 5
Goodness-of-Fit Statistics for WJ-R/KAIT Joint Confirmatory Factor Analyses

<table>
<thead>
<tr>
<th>Model</th>
<th>$\chi^2$</th>
<th>df</th>
<th>rmr</th>
<th>GFI</th>
<th>AGFI</th>
<th>PGFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial a priori models</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Spearman $g$</td>
<td>2419.1</td>
<td>322</td>
<td>.16</td>
<td>.42</td>
<td>.32</td>
<td>.36</td>
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<tr>
<td>Original $Gf$-$Gc$</td>
<td>2110.6</td>
<td>321</td>
<td>.19</td>
<td>.46</td>
<td>.37</td>
<td>.39</td>
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<tr>
<td>$Gf$-$Gc$ (KAIT) Five-Factor</td>
<td>1609.2</td>
<td>311</td>
<td>.21</td>
<td>.51</td>
<td>.41</td>
<td>.42</td>
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<tr>
<td>$Gf$-$Gc$ (KAIT) Six-Factor</td>
<td>1553.0</td>
<td>307</td>
<td>.21</td>
<td>.53</td>
<td>.42</td>
<td>.45</td>
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<tr>
<td>Contemporary $Gf$-$Gc$ (WJ-R) Seven-Factor</td>
<td>897.0</td>
<td>301</td>
<td>.11</td>
<td>.69</td>
<td>.62</td>
<td>.55</td>
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<tr>
<td>Contemporary $Gf$-$Gc$ (WJ-R) Eight-Factor</td>
<td>833.2</td>
<td>294</td>
<td>.10</td>
<td>.71</td>
<td>.63</td>
<td>.55</td>
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<tr>
<td>Expanded Contemporary $Gf$-$Gc$ (WJ-R) Eight-Factor</td>
<td>665.7</td>
<td>294</td>
<td>.09</td>
<td>.72</td>
<td>.65</td>
<td>.56</td>
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<td>Expanded Contemporary $Gf$-$Gc$ (WJ-R) Nine-Factor</td>
<td>608.4</td>
<td>286</td>
<td>.09</td>
<td>.75</td>
<td>.67</td>
<td>.57</td>
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<td>Post-Hoc/readjusted a priori models</td>
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<td>Contemporary $Gf$-$Gc$ (WJ-R) Seven-Factor</td>
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<td>302</td>
<td>.08</td>
<td>.68</td>
<td>.60</td>
<td>.55</td>
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<tr>
<td>Contemporary $Gf$-$Gc$ (WJ-R) Eight-Factor</td>
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<td>294</td>
<td>.08</td>
<td>.71</td>
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<td>.55</td>
</tr>
<tr>
<td>Expanded Contemporary $Gf$-$Gc$ (WJ-R) Eight-Factor</td>
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<td>.05</td>
<td>.71</td>
<td>.64</td>
<td>.56</td>
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<td>Expanded Contemporary $Gf$-$Gc$ (WJ-R) Nine-Factor</td>
<td>636.1</td>
<td>286</td>
<td>.05</td>
<td>.74</td>
<td>.66</td>
<td>.57</td>
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<tr>
<td>Post-Hoc Expanded Contemporary $Gf$-$Gc$ (WJ-R)</td>
<td>436.1</td>
<td>279</td>
<td>.04</td>
<td>.80</td>
<td>.73</td>
<td>.59</td>
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</tbody>
</table>

Note. GFI = Goodness-of-Fit Index; AGFI = Adjusted Goodness-of-Fit Index; PGFI = Parsimonious Goodness-of-fit Index; KAIT = Kaufman Adolescent and Adult Intelligence Test; WJ-R = Woodcock-Johnson-Revised.

(WJ-R) models, the differences are typically to the second decimal, and are not of major significance. This suggests that on empirical grounds, each of the four models are equally plausible. The fit statistics for the five post-hoc models were also not dramatically different. However, hierarchical chi-square ($p < .05$) tests between each respectively more complex model (e.g., Post-Hoc Expanded Contemporary $Gf$-$Gc$ and Expanded Contemporary Nine-Factor) found that each more complex model resulted in a significant improvement in model fit. When integrated with substantive considerations based on prior research and theory, we believe that arguments can be made in favor of the two post-hoc Expanded Contemporary $Gf$-$Gc$ (WJ-R) models.

Also, the confirmatory factor studies of McGhee and colleagues (e.g., McGhee & Leiberman, 1993), and, more importantly, Carroll’s (1993a) review of the extant factor analytic research, provide support for separate Memory Span (MS-Gsm) and Visual Memory (MV-Gsm) factors. The relatively low ($r = .20$) correlation between the Memory Span (MS-Gsm) and Visual Memory (MV-Gsm) factors in both Expanded Contemporary $Gf$-$Gc$ (WJ-R) models (see Table 6) also support this distinction.

The remaining issue is whether a model should maintain a distinction between the $Gc$ and Reading factors. The $Gc$ and Reading (RD/V-Grw) latent factor correlation ranged from .83 to .85 for the two Expanded Con-
### Table 6
Latent Factor Intercorrelations for Expanded Contemporary Gf-Gc (WJ-R) Eight-Factor (Figure 1) and Post-Hoc Expanded Contemporary Gf-Gc Models (Figure 3)

**Expanded Contemporary Gf-Gc (WJ-R) Eight-Factor Model**

<table>
<thead>
<tr>
<th></th>
<th>Gf</th>
<th>Gc</th>
<th>MS</th>
<th>MV</th>
<th>CS</th>
<th>PC</th>
<th>MA</th>
<th>RD/V</th>
<th>PS</th>
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<tr>
<td>Fluid Int. (Gf)</td>
<td></td>
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<td>Cryst. Int. (Gc)</td>
<td>.45</td>
<td>—</td>
<td>—</td>
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<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Mem. Span (MS-Gsm)</td>
<td>.34</td>
<td>.40</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Vis. Mem. (MV-Gom)</td>
<td>.40</td>
<td>.32</td>
<td>.20</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Clos. Speed (CS-Gv)</td>
<td>.38</td>
<td>.44</td>
<td>.18*</td>
<td>.59</td>
<td>—</td>
<td>—</td>
<td>—</td>
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</tr>
<tr>
<td>Phon. Cod. (PC-Ga)</td>
<td>.18*</td>
<td>.29</td>
<td>.18*</td>
<td>.35</td>
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<tr>
<td>As. Mem. (MA-Glr)</td>
<td>.35</td>
<td>.62</td>
<td>.44</td>
<td>.32</td>
<td>.36</td>
<td>.32</td>
<td>—</td>
<td>—</td>
<td>—</td>
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<tr>
<td>Reading (RD/V-Grw)</td>
<td>.46</td>
<td>.85</td>
<td>.45</td>
<td>.33</td>
<td>.42</td>
<td>.37</td>
<td>.62</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Per. Speed (PS-Gs)</td>
<td>.48</td>
<td>.20</td>
<td>.08*</td>
<td>.25</td>
<td>.30</td>
<td>.27</td>
<td>.14*</td>
<td>.25</td>
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**Post-Hoc Expanded Contemporary Gf-Gc (WJ-R) Model**

<table>
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<tr>
<th></th>
<th>I</th>
<th>RG</th>
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<th>RD/V</th>
<th>PS</th>
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<tr>
<td>Induction (I-Gf)</td>
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<tr>
<td>Seq. Rea. (RG-Gf)</td>
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<td>—</td>
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<td>Cryst. Int. (Gc)</td>
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<td>.44</td>
<td>—</td>
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<tr>
<td>Vis. Mem. (MV-Gom)</td>
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<td>.38</td>
<td>.32</td>
<td>.20</td>
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<td>Clos. Speed (CS-Gv)</td>
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<td>.36</td>
<td>.44</td>
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<td>Phon. Cod. (PC-Ga)</td>
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<td>.18*</td>
<td>.29</td>
<td>.18*</td>
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<td>As. Mem. (MA-Glr)</td>
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<td>.36</td>
<td>.32</td>
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<td>Reading (RD/V-Grw)</td>
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<td>.83</td>
<td>.48</td>
<td>.34</td>
<td>.44</td>
<td>.36</td>
<td>.61</td>
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<tr>
<td>Per. Speed (PS-Gs)</td>
<td>.48</td>
<td>.46</td>
<td>.20</td>
<td>.08*</td>
<td>.25</td>
<td>.30</td>
<td>.27</td>
<td>.14*</td>
<td>.25</td>
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* Indicates latent factor correlations that were not significantly different from zero (p < .05).

Note: MS = Memory Span; MV = Visual Memory; CS = Closure Speed; PC = Phonetic Coding; MA = Associative Memory; RD/V = Reading Decoding/Verbal (printed) Language Comprehension; PS = Perceptual Speed; I = Inductive; RG = General Sequential Reasoning; WJ-R = Woodcock-Johnson-Revised.

**Note.** MS = Memory Span; MV = Visual Memory; CS = Closure Speed; PC = Phonetic Coding; MA = Associative Memory; RD/V = Reading Decoding/Verbal (printed) Language Comprehension; PS = Perceptual Speed; I = Inductive; RG = General Sequential Reasoning; WJ-R = Woodcock-Johnson-Revised.
temporary Gf-Gc (WJ-R) models, a high value that might suggest the need for a single factor. However, one would need to add approximately five standard errors of the estimates (.03) to the Gc and Reading (RD/V-Grw) latent factor correlation before it would include the value of 1.0, a value indicating a single construct. Also, nonfactor analytic evidence in the form of different developmental growth curves for Gc and reading factors suggests that these are two different constructs (McGrew et al., 1991). Thus, we believe that the Expanded Contemporary Gf-Gc (WJ-R) Nine-Factor model, with the added post-hoc KAIT indicator-factor parameters, is one of the
most plausible *a priori* model fit of the WJ-R/KAIT data in this sample. The results for this model are presented in Figure 2. The latent factor correlations for this model are presented in Table 6.

The 10-factor model that was derived from the maximum amount of post-hoc modeling readjustment is presented in Figure 3. As would be expected given the derivation of this model, the fit statistics for the model (see Table 5) and chi-square comparison tests (\(p < .05\)) indicate that this model fit better than all other models. However, these fit statistics cannot accurately be compared to the *a priori* models without cross-validation in a new sample. Two important hypotheses are suggested by the 10-factor
model in Figure 3. First, the KAIT Definitions test may have additional variance associated with reading skills (viz., word recognition) as evidenced by the significant .13 correlated error term between this test and the WJ-R Letter-Word Identification test. Second, two first-order narrow \( G_f \) factors representing inductive (Induction-I) and deductive (General Sequential Reasoning-RG) reasoning might explain the relations between the four Fluid Intelligence (\( G_f \)) tests used in this study. The WJ-R Analysis-Synthesis and KAIT Logical Steps tests, and the WJ-R Concept Formation and KAIT Mystery Codes tests, may be indicators of deductive and inductive reasoning abilities, respectively. The .89 latent factor correlation between these two factors (see Table 5) reflects highly related factors. However, approximately five standard error of the estimates (i.e., .02) are needed before the latent factor correlation range includes a value of 1.0, the value indicating that the factors are identical. Carroll’s (1993a) review of the \( G_f \) factor research, which identifies two such separate abilities, would support the Induction (I) and General Sequential Reasoning (RG) distinction represented in Figure 3.

Finally, a review of the latent factor correlations for the models presented in Figures 2 and 3 (see Table 5) provide additional support for the contemporary \( G_f-G_c \) theory over less factorially complex models. With the exception of the two high correlations previously discussed, all of the latent factor correlations are generally low to moderate in magnitude. The size of these correlations indicate that the factors represented in the final two models (Figures 1 and 2) represent distinctly different human ability constructs.

**DISCUSSION**

Results of the confirmatory factor analyses of the 27 tests from the WJ-R, KAIT, and WISC-III demonstrated that a nine-factor model was the most plausible explanation of the data when considered within the context of contemporary \( G_f-G_c \) theory and research. The results of this investigation have important implications for understanding the structure of cognitive abilities in non-White populations and for test interpretation.

Given the increasing multicultural nature of the population, the finding that the best-fitting \( G_f-G_c \) models in the current non-White sample are similar to the \( G_f-G_c \) models found in predominantly White samples in the extant factor analytic research suggests that contemporary \( G_f-G_c \) theory may be useful for assessing and understanding cognitive functioning across different racial and ethnic groups. This conclusion is generally consistent with the available evidence presented by Carroll (1993a) that the \( G_f-G_c \) structure of intelligence is invariant across ethnic and culturally diverse groups. Given that this literature base is relatively limited (Carroll, 1993a), the current study offers additional support regarding this important theoretical issue.
In considering the present results within the context of test interpretation, several important implications are apparent. First, the KAIT Double Meanings and Definitions subtests are mixed measures of \( Gc \) and Reading ability (RD/V-Gw); the KAIT Auditory Comprehension subtests is a mixed measure of \( Gc \) and Memory Span (MS-Gsm); and the KAIT Auditory Comprehension Delayed Recall subtest is a mixed measure of \( Gc \) and Associative Memory (MA-Glr). Therefore, caution must be exercised when interpreting an individual’s performance on these subtests. When an individual displays a strength or weakness on one or more of the KAIT’s mixed factor subtests, it is recommended that practitioners administer purer measures of the \( Gf-Gc \) abilities that are assessed by these subtests before making interpretations regarding test performance. (See McGrew and Flanagan, 1998, for a listing of relatively pure measures of \( Gf-Gc \) abilities that may be used for this purpose). By contrast, none of the 14 WJ-R tests had mixed (or secondary) factor loadings in the current study, which is largely consistent with the extant WJ-R research. Therefore, the WJ-R tests can be considered relatively pure measures or indicators of their respective \( Gf-Gc \) factors.

A second implication relates to the generalizability of narrow stratum I indicators to broad stratum II \( Gf-Gc \) abilities. The present findings revealed that of the nine factors that provide the best explanation of the WJ-R and KAIT tests, only two can be considered broad stratum II factors (i.e., \( Gf \) and \( Gc \)). The \( Gf \) and \( Gc \) factors in the present study include at least two qualitatively different stratum I abilities. For example, two inductive reasoning tests (WJ-R Concept Formation and KAIT Mystery Codes) and two general sequential reasoning or deductive reasoning tests (WJ-R Analysis-Synthesis and KAIT Logical Steps) are the narrow ability indicators of \( Gf \) in the present study. Thus, whether considered together or separately, the WJ-R and KAIT batteries have two qualitatively different narrow ability indicators of \( Gf \).

Similarly, several tests of lexical knowledge (WJ-R Picture Vocabulary and Oral Vocabulary, KAIT Double Meanings and Definitions), a test of general information and information about culture (KAIT Famous Faces), and a test of language development and listening ability (KAIT Auditory Comprehension) comprise the stratum I indicators of \( Gc \) in the present study. However, although the combination of tests represented in this study show evidence of a broad stratum II \( Gc \) factor, when the WJ-R (Cognitive Battery) and KAIT composite scores are considered individually, there is no support for a broad \( Gc \) factor on either battery. That is, the two \( Gc \) stratum I indicators on the WJ-R Comprehension-Knowledge Cluster (i.e., Picture Vocabulary and Oral Vocabulary) are primarily measures of lexical knowledge. Therefore, interpretations that are made regarding an individual’s performance on the WJ-R Comprehension-Knowledge Cluster should be made at the narrow ability level (e.g., performance reflects primarily lexical
knowledge ability), since there is not enough diversity among these stratum I indicators of $Gc$ to warrant a broad or stratum II $Gc$ interpretation. When using the WJ-R, in order to generalize about an individual’s broad $Gc$ ability, practitioners will need to supplement their assessment with at least one or two additional stratum I indicators of $Gc$ (see McGrew & Flanagan, 1998).

Assessment of $Gc$ using the KAIT battery presents a different issue. That is, rather than including only one stratum I indicator of $Gc$, the KAIT includes three (lexical knowledge, information about culture, and listening ability); but, as stated above, with the exception of Famous Faces, the KAIT’s subtests that measure these stratum I abilities (i.e., Double Meanings, Definitions and Auditory Comprehension) are factorially complex. Thus, in order to obtain a clearer understanding of an individual’s performance in the area of crystallized intelligence, practitioner’s should supplement the KAIT’s intended $Gc$ subtests with purer stratum I indicators of $Gc$ and ensure that two or more of these narrow abilities are assessed.

A third implication that may be drawn from the present findings is that many of the $Gf$-$Gc$ factors that have been operationally defined in previous joint factor analyses of cognitive test batteries (e.g., McGhee, 1993; Woodcock, 1990) have confounded stratum I and II factors. Although the present results largely support the extant WJ-R research on the structure of this cognitive battery, it is important to realize that the WJ-R’s $Gs$, $Ga$, $Gbr$, $Gsm$ and $Gc$ factors are stratum I factors. That is, each of these factors are comprised of two tests that measure the same stratum I ability—Perceptual Speed (PS), Phonetic Coding (PC), Associative Memory (MA), Memory Span (MS), and Lexical Knowledge (VL), respectively. With the exception of the WJ-R’s $Gf$ factor, none of the $Gf$-$Gc$ factors include a sufficient breadth of narrow stratum I abilities to allow the practitioner to generalize about an individual’s functioning in the broad stratum II $Gf$-$Gc$ cognitive domains. However, practitioner’s need only supplement their measurement of each of these $Gf$-$Gc$ abilities with one qualitatively different and relatively pure stratum I indicator in order to gain a clearer understanding of broad functioning in the $Gf$-$Gc$ domains that are measured by the WJ-R. For example, the present findings show that the KAIT Famous Faces subtests would provide an excellent stratum I indicator of $Gc$ that is qualitatively different from those included on the WJ-R.

Another contribution of these findings is that they help to clarify the nature of the two WJ-R $Gv$ tests (i.e., Picture Recognition and Visual Closure). In previous studies of the factorial composition of tests 1 to 14 of the WJ-R Cognitive Battery, the $Gv$ factor was not as robust as all other $Gf$-$Gc$ factors (McGrew et al., 1991; Woodcock, 1990). The present results indicate that the WJ-R $Gv$ factor may be weak because Picture Recognition may measure primarily Visual Memory (MV; a stratum I indicator of $Gsm$) and Visual Closure may measure primarily Closure Speed (CS; a stratum I
indicator of Gv). Therefore, the WJ-R Gv cluster should be interpreted cautiously until further research is available to substantiate the underlying constructs of the cognitive tests that comprise this factor.

The present findings do not support the organizational structure of the KAIT. The originally proposed fluid-crystallized, two-factor model underlying the KAIT is too simple; it does not explain the array of Gf-Gc abilities that are necessary to solve the KAIT tasks. These results show that the KAIT has pure stratum I indicators of four Gf-Gc factors (i.e., Gf, Gc, Glr, Gsm). Of these factors, Gf is the only factor that may be interpreted as a broad stratum II ability. Although the KAIT Gc factor has qualitatively different stratum I indicators, a broad Gc interpretation should be made cautiously since, with the exception of Famous Faces, these indicators are mixed factor subtests. The KAIT also has two strong measures of Associative Memory (Rebus Learning and Rebus Learning-Delayed Recall), which are narrow indicators of Glr, and one strong measure of Visual Memory (Memory for Block Designs), which is a narrow indicator of Gsm.

Since this was the first study to factor analyze the KAIT subtests with strong measures of Fluid Reasoning, these findings provide preliminary support for the construct validity of two of the four Fluid subtests on the KAIT battery (i.e., Logical Steps and Mystery Codes). The other purported Fluid subtests of the KAIT (i.e., Rebus Learning and Memory for Block Design) are strong indicators of Glr and Gsm, respectively. Therefore, the KAIT Fluid Scale IQ (which is comprised of Logical Steps, Mystery Codes and Rebus Learning), is a confounded (or mixed) measure of Fluid Reasoning and Associative Memory. The extent to which the KAIT Fluid Scale IQ is confounded by other Gf-Gc abilities will vary depending on whether or not the KAIT’s alternate Fluid subtest (Memory for Block Designs) is substituted for a Core Battery subtest (Flanagan et al., 1994). For example, if Memory for Block Designs is substituted for Rebus Learning, then the Fluid Scale IQ will be a confounded measure of Fluid Reasoning and Visual Memory. However, if Memory for Block Designs is substituted for either Logical Steps or Mystery Codes, then the Fluid Scale IQ will be a confounded measure of Fluid Reasoning, Associative Memory and Visual Memory. In the latter situation, it appears that the KAIT Fluid Scale IQ would provide a better estimate of an individual’s broad memory ability than his/her fluid reasoning ability.

The KAIT’s Crystallized Scale IQ is also confounded by other Gf-Gc abilities. For example, significant Grw loadings for the Definitions and Double Meanings subtests as well as the correlated error between Definitions and Letter-Word Identification in post-hoc analyses suggest that these tests involve reading ability. As a result, they may be problematic when assessing adolescents and adults who are suspected of having a reading disability. Although it was never the authors’ intention to construct pure Fluid and Crystallized scales (Kaufman & Kaufman, 1993), some researchers contend
that it is more difficult to interpret mixed as opposed to pure measures of ability (e.g., Flanagan et al., 1994; Woodcock, 1990). Likewise, confounded measures of ability may lead to difficulty in understanding individual cognitive strengths and weaknesses and in planning educational interventions.

A number of study limitations suggest fruitful avenues for future research. First, the ratio (4.2:1) of subjects \( (N = 114) \) to variables \( (N = 27) \) for this study was just below the minimum \( (N = 5) \) and recommended \( (N = 10) \) subjects per variable guidelines commonly suggested. However, explicit subject-to-variable sample size guidelines have "always been in flux, passed down from generations of factor analysts in an oral tradition" (Floyd & Widaman, 1995, p. 289). The ratio and sample size in the current study is close to Streiner’s (1994) 5:1 recommended minimum ratio, a ratio that is adequate for sample sizes of 100 or more. More importantly, Guadagnoli and Velicer (1988) and Raykov and Widaman (1995) suggest that the issue is more complex than a fixed subject-to-variable ratio and that there is no clear theoretical and/or empirical foundation for most standard subject-to-variable rules-of-thumb. Their research suggests that variable saturation with the factors (as indicated by the size of the factor loadings), together with sample size and the number of variables is more important. They report that when factor loadings are .80 or above, highly stable factor solutions can be found in samples as small as 50, regardless of the number of indicators. In the current study, the vast majority of primary factor loadings for the tests were .90 or above. According to Guadagnoli’s and Velicer’s (1988) conclusions, the presence of such highly factor saturated variables in the current sample of 114 would suggest that the current results would be stable in additional samples.

Second, although we recognize that the restricted composition and size of our sample limits generalization to other populations, knowledge about the factorial structure of \( Gf-Gc \) abilities in the current non-White sample is a contribution to the relatively limited \( Gf-Gc \) multicultural literature. Because of the demographically limited nature of the current sample, together with the unresolved issue of what is an ideal sample size for a confirmatory factor analysis study, we argue for caution in generalizing the results from this non-White sample to other non-White samples, as well as similar samples at different developmental levels, until appropriate cross-validation investigations are completed.

Third, the interpretability of future studies will be more meaningful if at least three qualitatively different indicators for all stratum II factors are included. Finally, the current results only evaluated the \( WJ-R \) and KAIT batteries within the contemporary \( Gf-Gc \) theoretical framework. Alternative models based on other theoretical approaches to understanding intelligence (e.g., the PASS model; Das, Naglieri, & Kirby, 1994) need to be specified and evaluated.

In conclusion, the present findings contribute to the theoretical litera-
ture by supporting the invariance of a contemporary $Gf$-$Gc$ model in a non-White sample. In addition, this study showed that when a sufficiently diverse array of cognitive tests are used, “older” simple (e.g., dichotomous) models are not supported; rather, a contemporary empirically derived $Gf$-$Gc$ theoretical model of multiple cognitive abilities is supported. It was found that most of the $Gf$-$Gc$ factors that are represented on the WJ-R and KAIT batteries warrant a narrow stratum I (and not a broad stratum II) interpretation. An examination of other major intelligence tests batteries reveals that the same interpretive limitations are apparent (see McGrew, 1997; McGrew & Flanagan, 1998). This suggests that practitioners should recognize the breadth and depth of coverage of cognitive abilities on intelligence test batteries and “cross” batteries when necessary to ensure that a sufficient range of stratum I indicators are assessed before generalizing about functioning in broad $Gf$-$Gc$ domains (Flanagan & McGrew, 1995a, 1995b, 1997; McGrew, 1997; McGrew & Flanagan, 1998; Woodcock, 1990). It is important to understand what constructs are measured by cognitive ability tests such as the KAIT and WJ-R in all cultural groups given the existing and emerging literature on the differential predictive relationships between broad and narrow cognitive $Gf$-$Gc$ abilities and academic and occupational achievement (e.g., Friedman, 1995; Geary, 1993; Humphreys, Lubinski, & Yao, 1993; McGrew, 1993; McGrew & Flanagan, 1998) (see also McGrew & Flanagan, 1998 for a comprehensive review). For example, there is a larger body of evidence that supports a strong relationship between phonological processing (which is represented by the Phonetic Coding / $Ga$ factor in the present study) and reading achievement (see Felton & Pepper, 1995; McBride-Chang, 1995; Wagner & Torgesen, 1987). Moreover, recent research with nationally representative samples across the school age years has demonstrated that some $Gf$-$Gc$ abilities are not only important in understanding and predicting reading achievement, but they also predict significantly beyond a general ability construct (see McGrew et al., 1997).

The present results were interpreted within the context of contemporary $Gf$-$Gc$ theory and research (e.g., Horn, 1991; Horn & Noll, 1997) and Carroll’s (1993a) theoretical framework was used to demonstrate the importance of considering strata rather than order when interpreting factor analytic results. It is recommended that researchers use Carroll’s (1993a) taxonomy and definitions of factors in future joint factor analytic studies to aid in the interpretation of results. If future factor analytic studies ensure that a broad range of human cognitive abilities are represented and are interpreted from empirically supported theoretical frameworks (such as a contemporary $Gf$-$Gc$ model), then the field of intellectual assessment will begin to move toward a consistent terminology and theoretical model that will aid in understanding human cognitive functioning and that will help to narrow the gap between cognitive assessment and cognitive science.
REFERENCES


