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The Impact of the Cattell–Horn–Carroll Theory on Test Development and Interpretation of Cognitive and Academic Abilities

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In recent years, the *Cattell–Horn–Carroll* (CHC) theory has had a significant impact on the measurement of cognitive abilities and the interpretation of intelligence test performance. The purpose of this chapter is to summarize the most salient ways in which CHC theory has influenced the field of intellectual assessment. The chapter begins with a brief summary of the evolution of CHC theory. Next, the specific ways in which current CHC theory and research have influenced test development are presented. Finally, the CHC cross-battery approach is described as one mechanism through which practitioners in the field of psychoeducational assessment have embraced CHC theory, particularly as it applies to test interpretation.

BRIEF HISTORY OF THE CHC THEORY

The CHC theory is the most comprehensive and empirically supported psychometric theory of the structure of cognitive and academic abilities to date. It represents the integrated works of Raymond Cattell, John Horn, and John Carroll (Flanagan, McGrew, & Ortiz, 2000; McGrew, Chapter 8, this volume; Neisser et al., 1996). Because it has an impressive body of empirical support in the research literature (e.g., developmental, neurocognitive, outcome criterion), it is used extensively as the foundation for selecting, organizing, and interpreting tests of intelligence and cognitive abilities (e.g., Flanagan et al., 2000; Flanagan & Ortiz, 2001; McGrew & Flanagan, 1998). Most recently, it has been used for classifying achievement tests to (1) facilitate interpretation of academic abilities, and (2) provide a foundation for organizing assessments for individuals suspected of having a learning disability (Flanagan, Ortiz, Alfonso, & Mascolo, 2002). In addition, CHC theory is the foundation on which many new and recently revised intelligence batteries have been based (see Kaufman, Kaufman, Kaufman-Singer, & Kaufman, Chapter 16, this volume; Roid & Pomplun, Chapter 15, this volume; Schrank, Chapter 17, this volume). Because the evolution of CHC theory is described in depth by

McGrew (Chapter 8, this volume) and Horn and Blankson (Chapter 3, this volume), only a brief overview is presented here.

Original Gf-Gc Theory: First Precursor to CHC Theory

The original Gf-Gc theory was a dichotomous conceptualization of human cognitive ability put forth by Raymond Cattell in the early 1940s. Cattell based his theory on the factor-analytic work of Thurstone conducted in the 1930s. Cattell believed that *fluid intelligence* (Gf) included inductive and deductive reasoning abilities that were influenced by biological and neurological factors, as well as incidental learning through interaction with the environment. He postulated further that *crystallized intelligence* (Gc) consisted primarily of acquired knowledge abilities that reflected, to a large extent, the influences of acculturation (Cattell, 1957, 1971).

In 1965, John Horn expanded the dichotomous Gf-Gc model to include four additional abilities, including *visual perception or processing* (Gv), *short-term memory* (*short-term acquisition and retrieval*—SAR or Gsm), *long-term storage and retrieval* (*tertiary storage and retrieval*—TSR or Glr), and *speed of processing* (Gs). Later he added *auditory processing ability* (Ga) to the theoretical model and refined the definitions of Gv, Gs, and Glr (Horn, 1968; Horn & Stankov, 1982).

In the early 1990s, Horn added a factor representing an individual's quickness in reacting (*reaction time*) and making decisions (*decision speed*). The abbreviation for this factor is Gt (Horn, 1991). Finally, factors for *quantitative ability* (Gq) and *broad reading/writing ability* (Gw) were added to the model, based on the research of Horn (e.g., 1991) and Woodcock (1994), respectively. Based largely on the results of Horn's thinking and research, Gf-Gc theory expanded into an eight-factor model that became known as the Cattell–Horn Gf-Gc theory (Horn, 1991; see also Horn & Blankson, Chapter 3, this volume).

Carroll's Three-Stratum Theory: Second Precursor to CHC Theory

In his seminal review of the world's literature on human cognitive abilities, Carroll (1993) proposed that the structure of cognitive abilities could be understood best via three strata that differ in breadth and generality. The broadest and most general level of ability is represented by stratum III. According to Carroll, stratum III represents a general factor consistent with Spearman's (1927) concept of *g* and subsumes both broad (stratum II) and narrow (stratum I) abilities. The various broad (stratum II) abilities, are denoted with an uppercase *G* followed by a lowercase letter (e.g., Gf and Gc). The eight broad abilities included in Carroll's theory subsume a large number of narrow (stratum I) abilities (Carroll, 1993; see also Carroll, Chapter 4, this volume).[1]

The Cattell–Horn and Carroll Theories: Similarities and Differences

Figure 9.1 includes the Cattell–Horn Gf-Gc theory and Carroll's three-stratum theory (without the narrow abilities). These theories are presented together in order to highlight the most salient similarities and differences between them. Each theory posits that there are multiple broad (stratum II) abilities, and for the most part, the names and abbreviations associated with these abilities are similar or identical. Briefly, there are four major structural differences between the Carroll and Cattell–Horn theories. First, Carroll's theory includes a general ability factor (stratum III); the Cattell–Horn theory does not. Second, the Cattell–Horn theory includes quantitative knowledge and quantitative reasoning as a separate broad ability (i.e., Gq), whereas Carroll's theory includes quantitative reasoning as a narrow ability subsumed by Gf. This difference is depicted in Figure 9.1 by the arrow that leads from Gq in the Cattell–Horn theory to Gf in Carroll's theory. Third, the Cattell–Horn theory includes a broad reading/writing (Grw) factor; Carroll's theory includes reading and writing as narrow abilities subsumed by Gc. This difference is depicted in Figure 9.1 by the arrow that leads from Grw in the Cattell–Horn theory to Gc in Carroll's theory. Fourth, Carroll's theory includes short-term memory with other memory abilities, such as associative memory, meaningful memory, and free-recall memory, under Gy in Figure 9.1; the Cattell–Horn theory separates short-term memory (Gsm) from associative mem-

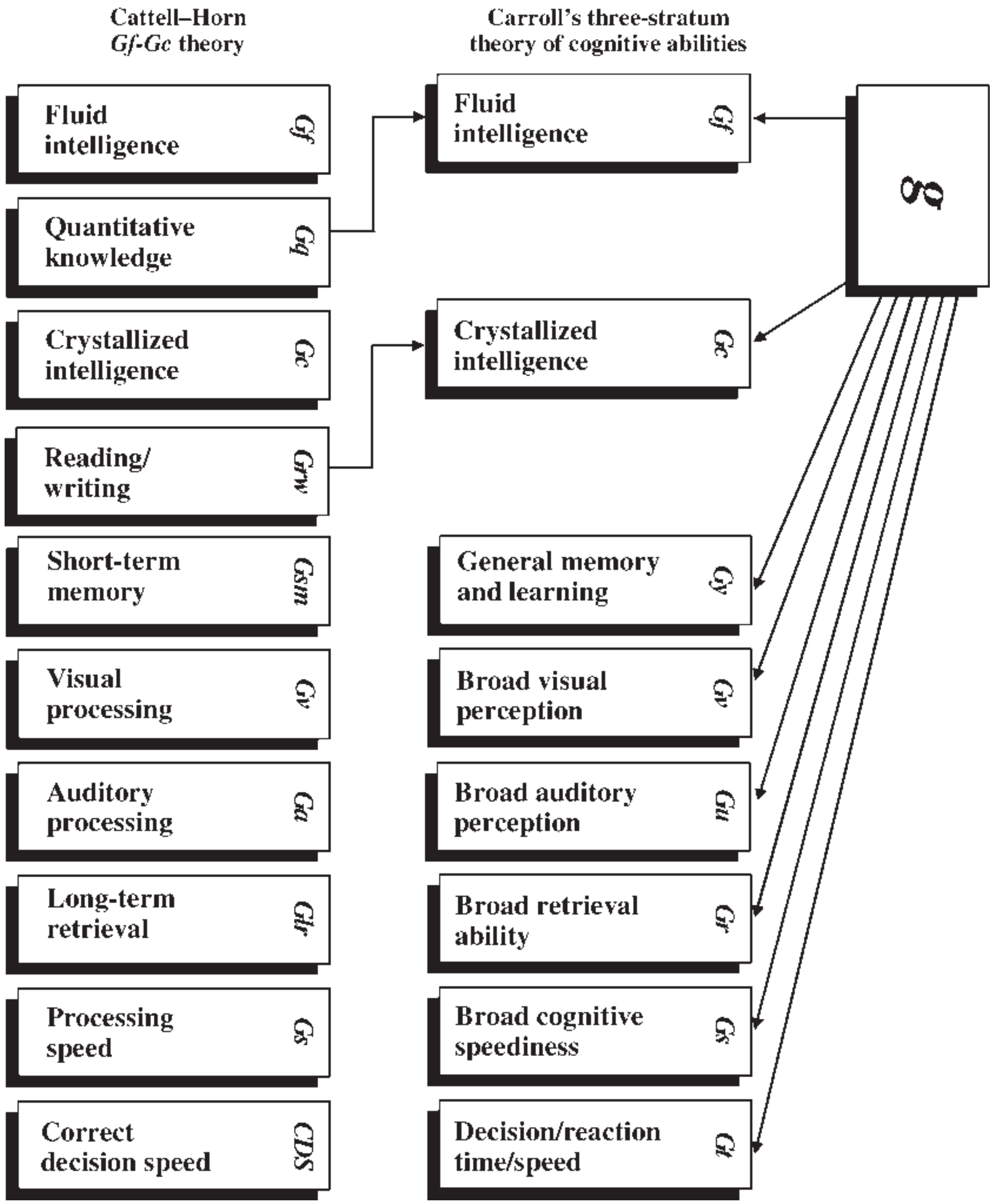

FIGURE 9.1. Comparison of Cattell–Horn Gf-Gc and Carroll three-stratum theories. Narrow abilities are omitted from this figure. From Flanagan, Ortiz, Alfonso, and Mascolo (2002). Published by Allyn and Bacon, Boston, MA. Copyright © 2002 by Pearson Education. Reprinted by permission.

ory, meaningful memory, and free-recall memory, because the latter abilities are purported to measure long-term retrieval (Glr in Figure 9.1). Notwithstanding these differences, Carroll (1993) concluded that the Cattell–Horn Gf-Gc theory represents the most reasonable approach to the structure of cognitive abilities currently available.

Current CHC Theory

In the late 1990s, McGrew (1997) attempted to resolve differences between the Cattell–Horn and Carroll models on the basis of his research. McGrew proposed an "integrated" Gf-Gc theory in Flanagan and colleagues (2000). This integrated theory became known as the Cattell–Horn–Carroll (CHC) theory of cognitive abilities shortly thereafter (see McGrew, Chapter 8, this volume, for details). CHC theory is depicted in Figure 9.2. This figure shows that CHC theory currently consists of 10 broad cognitive abilities and more than 70 narrow abilities.

The CHC theory presented in Figure 9.2 omits a *g* or general ability factor, primarily because the utility of the theory (as it is employed in assessment-related disciplines) is in clarifying individual cognitive and academic strengths and weaknesses, which are understood best through the operationalization of broad (stratum II) and narrow (stratum I) abilities (Flanagan & Ortiz, 2001). Others, however, believe that *g* is the most important ability to assess because it predicts the lion's share of the variance in multiple outcomes, both academic and occupational (e.g., Glutting, Watkins, & Youngstrom, 2003). Notwithstanding one's position on the importance of *g* in understanding various outcomes (particularly academic), there is considerable evidence that both broad and narrow CHC cognitive abilities explain a significant portion of variance in specific academic abilities, over and above the variance accounted for by *g* (e.g., McGrew, Flanagan, Keith, & Vanderwood, 1997; Vanderwood, McGrew, Flanagan, & Keith, 2002).

The various revisions of and refinements to the theory of fluid and crystallized intelligence over the past several decades, along with its mounting network of validity evidence, only began to influence intelligence test development recently—in the middle to late 1980s. Today, however, nearly every intelligence test developer acknowledges the importance of CHC theory in defining and interpreting cognitive ability constructs, and most have used this theory to guide directly the development of their intelligence tests. The increased importance given to CHC theory in intelligence test development is summarized next.

INTELLIGENCE TESTS PUBLISHED PRIOR TO 1998: WHAT ABILITIES WERE MEASURED?

Although there was substantial evidence of at least eight or nine broad cognitive Gf-Gc abilities by the late 1980s, the tests of the time did not reflect this diversity in measurement. Table 9.1 shows the intelligence batteries that were published between 1981 and 1997. The information presented in this table was derived from a series of joint factor analyses conducted by Woodcock (1990) and others (Carroll, 1993; Flanagan & McGrew, 1997; Horn, 1991; Keith, 1997; Keith, Kranzler, & Flanagan, 2001; McGrew, 1997; Phelps, McGrew, Knopik, & Ford, in press). As Table 9.1 shows, the majority of tests published prior to 1998 measured only two or three broad cognitive abilities well (i.e., included two or more measures of the broad ability). For example, this table shows that the Wechsler Preschool and Primary Scale of Intelligence—Revised (WPPSI-R), the Kaufman Assessment Battery for Children (K-ABC), the Kaufman Adolescent and Adult Intelligence Test (KAIT), the Wechsler Adult Intelligence Scale—Revised (WAIS-R), and the Cognitive Assessment System (CAS) batteries only measured two or three broad CHC abilities adequately. The WPPSI-R primarily measured Gv and Gc. The K-ABC primarily measured Gv and Gsm, and to a much lesser extent Gf, while the KAIT primarily measured Gc and Glr, and to a much lesser extent Gf and Gv. The CAS measured Gs, Gsm, and Gv. Finally, while the Differential Ability Scales (DAS), the Stanford–Binet Intelligence Scale: Fourth Edition (SB-IV), and the Wechsler Intelligence Scale for Children—Third Edition (WISC-III) did not provide sufficient coverage of abilities to narrow the gap between contemporary theory and practice, their comprehensive measurement of approxi-

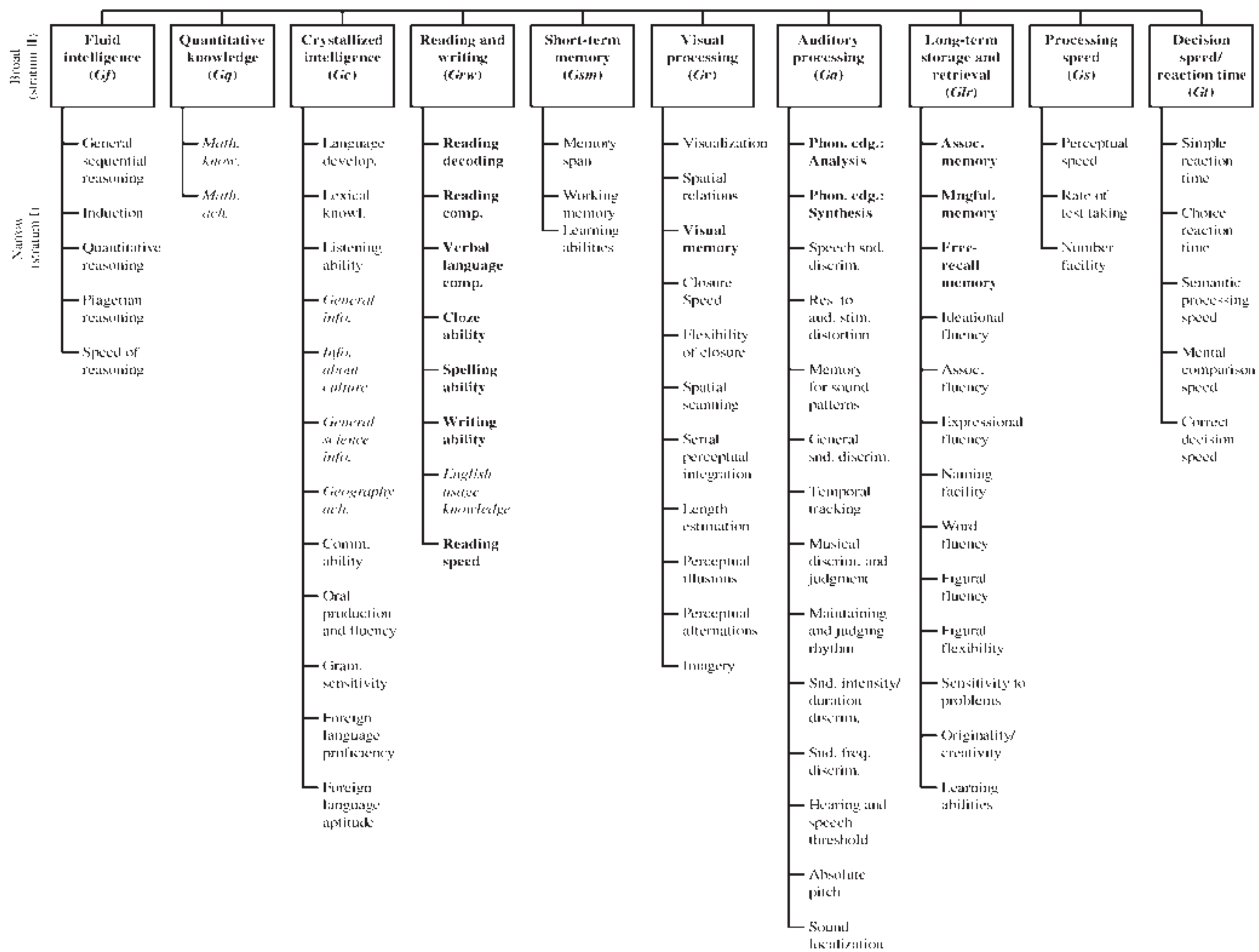

FIGURE 9.2. The Cattell–Horn–Carroll (CHC) theory of cognitive abilities. *Italic type* indicates abilities that were not included in Carroll's three-stratum theory, but were included by Carroll in the domains of knowledge and achievement. **Boldface type** indicates abilities that are placed under different CHC broad abilities than in Carroll's theory. These changes are based on the Cattell–Horn theory and/or recent research (see Flanagan et al., 2000; Flanagan & Ortiz, 2001; McGrew, 1997; McGrew & Flanagan, 1998). From Flanagan, Ortiz, Alfonso, and Mascolo (2002). Published by Allyn and Bacon, Boston, MA. Copyright © 2002 by Pearson Education. Reprinted by permission.

TABLE 9.1. Representation of Broad CHC Abilities on Nine Intelligence Batteries Published Prior to 1998

Battery	Gf	Gc	Gv	Gsm	Glr	Ga	Gs
WISC-III	—	Vocabulary Information Similarities Comprehension	Block Design Object Assembly Picture Arrangement Picture Completion Mazes	Digit Span	—	—	Symbol Search Coding
WAIS-R	—	Vocabulary Information Similarities Comprehension	Block Design Object Assembly Picture Completion Picture Arrangement	Digit Span	—	—	Digit–Symbol
WPPSI-R	—	Vocabulary Information Similarities Comprehension	Block Design Object Assembly Picture Completion Mazes Geometric Design	Sentences	—	—	Animal Pegs
KAIT	Mystery Codes Logical Steps	Definitions Famous Faces Auditory Comprehension Double Meanings	Memory for Block Designs	—	Rebus Learning Rebus Delayed Recall Auditory Delayed Recall	—	—
K-ABC	Matrix Analogies	—	Triangles Face Recognition Gestalt Closure Magic Window Hand Movements Spatial Memory Photo Series	Number Recall Word Order	—	—	—
CAS	—	—	Figure Memory Verbal Spatial Relations	Word Series Sentence Repetition	—	—	Matching Numbers Receptive Attention Planned Codes

			Nonverbal Matrices	Sentence Questions			Number Detection Planned Connections Expressive Attention
DAS	Matrices Picture Similarities Sequential and Quantitative Reasoning	Similarities Verbal Comprehension Word Definitions Naming Vocabulary	Pattern Construction Block Building Copying Matching Letter-Like Forms Recall of Designs Recognition of Pictures	Recall of Digits	Recall of Objects	—	Speed of Information Processing
WJ-R	Concept Formation Analysis–Synthesis	Oral Vocabulary Picture Vocabulary Listening Comprehension Verbal Analogies	Spatial Relations Picture Recognition Visual Closure	Memory for Words Memory for Sentences Numbers Reversed	Memory for Names Visual–Auditory Learning Delayed Recall: Memory for Names Delayed Recall: Visual–Auditory Learning	Incomplete Words Sound Blending Sound Patterns	Visual Matching Cross Out
SB-IV	Matrices Equation Building Number Series	Verbal Relations Comprehension Absurdities Vocabulary	Pattern Analysis Bead Memory Copying Memory for Objects Paper Folding and Cutting	Memory for Sentences Memory for Digits	—	—	—

Note. CHC classifications are based on the extant literature and primary sources such as Woodcock (1990), Horn (1991), Carroll (1993), McGrew (1997), and McGrew and Flanagan (1998). WISC-III, Wechsler Intelligence Scale for Children—Third Edition (Wechsler, 1991); WAIS-R, Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981); WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence—Revised (Wechsler, 1989); KAIT, Kaufman Adolescent and Adult Intelligence Test (Kaufman & Kaufman, 1993); K-ABC, Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983); CAS, Cognitive Assessment System (Das & Naglieri, 1997); DAS, Differential Ability Scales (Elliott, 1990); WJ-R, Woodcock–Johnson Psycho-Educational Battery—Revised (Woodcock & Johnson, 1989); SB-IV, Stanford–Binet Intelligence Scale: Fourth Edition (Thorndike, Hagen, & Sattler, 1986).

mately four CHC abilities, as depicted in Table 9.1, was nonetheless an improvement over the above-mentioned batteries. Table 9.1 shows that only the Woodcock–Johnson Psycho-Educational Battery—Revised (WJ-R) included measures of all broad cognitive abilities listed in the table. Nevertheless, most of the broad abilities were not measured adequately by the WJ-R (McGrew & Flanagan, 1998).

In general, Table 9.1 shows that Gf, Gsm, Glr, Ga, and Gs were not measured well by the majority of intelligence tests published prior to 1998. Therefore, it is clear that most test authors did not use the theory of fluid and crystallized intelligence and its corresponding research base to guide the development of their intelligence tests. As such, a substantial theory–practice gap existed; that is, theories of the structure of cognitive abilities were far in advance of the instruments used to operationalize them. In fact, prior to the mid-1980s, theory seldom played a role in intelligence test development. The numerous dashes in Table 9.1 exemplify the theory–practice gap that existed in the field of intellectual assessment at that time.

A METHOD DESIGNED TO NARROW THE THEORY–PRACTICE GAP: THE CHC CROSS-BATTERY APPROACH

As a result of his findings, Woodcock (1990) suggested that it might be necessary to "cross" batteries to measure a broader range of cognitive abilities. As such, the findings presented in Table 9.1 provided the impetus for the development of the cross-battery approach (McGrew & Flanagan, 1998). This approach to assessment (currently known as the *CHC cross-battery approach*, and referred to hereafter as the CB approach) is a time-efficient method of assessment and interpretation that is grounded in CHC theory and research. The CB approach provides a set of principles and procedures that allows practitioners to measure a wider range of abilities than that represented by most single intelligence or achievement batteries, in a theoretically and psychometrically defensible manner. In effect, the CB approach was developed to systematically replace the dashes in Table 9.1 with tests from another battery. As such, this approach guides practitioners in the selection of tests, both core and supplemental, that together provide measurement of abilities that is considered sufficient in both breadth and depth for the purpose of addressing referral concerns. Furthermore, the CB approach details a hypothesis generation model of test interpretation that is grounded in current research. The section that follows briefly summarizes the three pillars or foundational sources of information that underlie the CB approach (Flanagan & Ortiz, 2001).

The Three Pillars of the CB Approach

The first pillar of the CB approach is CHC theory. This theory was selected to guide assessment and interpretation because it is based on a more thorough network of validity evidence than other contemporary multidimensional ability models of intelligence (see McGrew & Flanagan, 1998; Messick, 1992; Sternberg & Kaufman, 1998). According to Daniel (1997), the strength of this model is that it was arrived at "by synthesizing hundreds of factor analyses conducted over decades by independent researchers using many different collections of tests. Never before has a psychometric ability model been so firmly grounded in data" (pp. 1042–1043). Because the broad and narrow abilities that constitute CHC theory have been defined elsewhere in this book (see Horn & Blankson, Chapter 3, this volume; McGrew, Chapter 8, this volume), these definitions will not be reiterated here.

The second pillar of the CB approach consists of the CHC broad (stratum II) classifications of cognitive and academic ability tests. Specifically, based on the results of a series of cross-battery confirmatory factor analysis studies of the major intelligence batteries and task analyses of many test experts, Flanagan and colleagues classified all the subtests of the major cognitive and achievement batteries according to the particular CHC broad abilities they measured. To date, over 500 CHC broad-ability classifications have been made, based on the results of these studies. These classifications of cognitive and academic ability tests assist practitioners in identifying measures that assess various aspects of the broad abilities (such as Gf, Gc, Gq, and Grw) represented in CHC theory. Classification of tests at the broad-ability level is necessary to improve upon the validity of cognitive assessment and interpretation. Specifically, broad-ability classifications ensure that the CHC constructs underlying assessments are minimally affected by *construct-irrelevant variance* (Messick, 1989, 1995). In other words, knowing what tests measure what abilities enables clinicians to organize tests into *construct-relevant* clusters—clusters containing only measures that are *relevant to* the construct or ability of interest.

The third pillar of the CB approach consists of the CHC narrow (stratum I) classifications of cognitive and academic ability tests. These classifications were originally reported in McGrew (1997). Subsequently, Caltabiano and Flanagan (2004) have provided content validity evidence for the narrow-ability classifications underlying the major intelligence and achievement batteries. Use of narrow-ability classifications were necessary to ensure that the CHC constructs underlying assessments are well represented. That is, the narrow-ability classifications of tests assist practitioners in combining qualitatively different indicators (or tests) of a given broad ability into clusters, so that appropriate inferences can be made from test performance. Taken together, the three pillars underlying the CB approach provide the necessary foundation for organizing assessments of cognitive and academic abilities that are theoretically driven, comprehensive, and valid.

IMPACT OF CHC THEORY AND CB CLASSIFICATIONS ON TEST DEVELOPMENT

In the past decade, Gf-Gc theory, and more recently CHC theory, have had a significant impact on the revision of old intelligence batteries and development of new ones. For example, a wider range of broad and narrow abilities is represented in current intelligence batteries than that which was represented in previous editions of these tests. Table 9.2 provides several salient examples of the impact that CHC theory and the resulting CB classifications have had on intelligence test development over the past two decades. This table lists the major intelligence tests in the order in which they were revised, beginning with those tests with the greatest number of years between revisions (i.e., the K-ABC and its second edition, the KABC-II) and ending with newly developed tests and tests that at this writing have yet to be revised (e.g., the Wide Range Intelligence Test [WRIT] and DAS, respectively). As is obvious from a review of Table 9.2, CHC theory and CB classifications have had a significant impact on recent test development.

Of the seven intelligence batteries (including both comprehensive and brief measures) that were published since 2000, the test authors of three clearly used CHC theory and CB classifications as a blueprint for test development (i.e., the WJ III, SB5, and KABC-II), and the test authors of two were obviously influenced by CHC theory (i.e., the Reynolds Intellectual Assessment Scales [RIAS] and WRIT). Only the authors of the most recent Wechsler scales (i.e., the WPPSI-III, WISC-IV, and WAIS-III) have not stated explicitly that CHC theory was used as a guide for revision. Nevertheless, these authors acknowledge the research of Cattell, Horn, and Carroll in their most recent manuals (Wechsler, 2002, 2003). Presently, as Table 9.2 shows, nearly all intelligence batteries that are used with some regularity subscribe either explicitly or implicitly to CHC theory.

The obvious adherence to CHC theory may be seen also in Table 9.3. This table is identical to Table 9.1, except that it also includes the subtests from the most recent revisions of the tests from Table 9.2. A review of Table 9.3, which includes all intelligence batteries that have been published after 1998, shows that many of the gaps in measurement of broad cognitive abilities have been filled. Specifically, the majority of tests published after 1998 now measure four or five broad cognitive abilities adequately, as compared to two or three. For example, Table 9.3 shows that the WISC-IV, WAIS-III, WPPSI-III, KABC-II, and SB5 all measure four or five broad CHC abilities. The WISC-IV measures Gf, Gc, Gv, Gsm, and Gs, while the KABC-II measures Gf, Gc, Gv, Gsm, and Glr. The WAIS-III measures Gc, Gv, Gsm, and Gs adequately, and to a lesser extent Gf, while the WPPSI-III measures Gc, Gv/Gf, and Gs

TABLE 9.2. Impact of the CHC Theory on Intelligence Test Development

Test (year of publication) CHC impact	**Revision (year of publication)** CHC impact
K-ABC (1983) No obvious impact.	**KABC-II** (2004) Provides a second global score that includes crystallized ability. Includes several new subtests measuring reasoning. Interpretation of test performance may be based on CHC theory or Luria's theory. Provides assessment of five CHC broad abilities. (See Kaufman et al., Chapter 14, this volume.)
SB-IV (1986) Used a three-level hierarchical model of the structure of cognitive abilities to guide construction of the test. The top level included the general reasoning factor or *g*; the middle level included three broad factors called Crystallized Abilities, Fluid-Analytic Abilities, and Short-Term Memory; the third level included more specific factors, including Verbal Reasoning, Quantitative Reasoning, and Abstract/Visual Reasoning.	**SB5** (2003) CHC theory has been used to guide test development. Increases the number of broad factors from four to five. Includes a Working Memory factor, based on research indicating its importance for academic success. (See Roid & Pomplum, Chapter 15, this volume.)
WAIS-R (1981) No obvious impact.	**WAIS-III** (1997) Enhances the measurement of fluid reasoning by adding the Matrix Reasoning subtest. Includes four Index scores that measure specific abilities more purely than the traditional IQs provided in the various Wechsler scales. Includes a Working Memory Index, based on recent research indicating its importance for academic success.
WPPSI-R (1989) No obvious impact.	**WPPSI-III** (2002) Incorporates measures of Processing Speed that yield a Processing Speed Quotient, based on recent research indicating the importance of processing speed for early academic success. Enhances the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests.
WJ-R (1989) Modern Gf-Gc theory was used as the cognitive model for test development. Included two measures of each of eight broad abilities.	**WJ III** (2001) CHC theory has been used as a "blueprint" for test development. Includes two or three qualitatively different narrow abilities for each broad ability. The combined Cognitive and Achievement batteries of the WJ III include 9 of the 10 broad abilities subsumed in CHC theory.
WISC-III (1991) No obvious impact.	**WISC-IV** (2003) Eliminates Verbal and Performance IQs, adhering more closely to CHC theory. Replaces the Freedom from Distractibility Index with the Working Memory Index, a purer measure of working memory. Replaces the Perceptual Organization Index with the Perceptual Reasoning Index. Enhances the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests. Enhances the measurement of processing speed with the addition of the Cancellation subtest.

(continued)

TABLE 9.2. *(continued)*

Test (year of publication) CHC impact	**Revision (year of publication)** CHC impact
RIAS (2003) Includes indicators of fluid and crystallized abilities.	
WRIT (2002) Has been developed to be consistent with current theories of intelligence. Evaluates multiple abilities. Provides Crystallized and Fluid IQs based on Cattell–Horn theory.	
CAS (1997) No obvious impact.	
KAIT (1993) Includes subtests organized according to the work of Horn and Cattell. Provides Fluid and Crystallized IQs.	
DAS (1990) No obvious impact.	

Note. K-ABC, Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983); KABC-II, Kaufman Assessment Battery for Children—Second Edition (Kaufman & Kaufman, 2004); SB-IV, Stanford–Binet Intelligence Scale: Fourth Edition (Thorndike et al., 1986); SB5, Stanford–Binet Intelligence Scales, Fifth Edition (Roid, 2003); WAIS-R, Wechsler Adult Intelligence Scale—Revised (Wechsler, 1981); WAIS-III, Wechsler Adult Intelligence Scale—Third Edition (Wechsler, 1997); WPPSI-R, Wechsler Preschool and Primary Scale of Intelligence—Revised (Wechsler, 1989); WPPSI-III, Wechsler Preschool and Primary Scale of Intelligence—Third Edition (Wechsler, 2002); WJ-R, Woodcock–Johnson Psycho-Educational Battery—Revised (Woodcock & Johnson, 1989); WJ III, Woodcock–Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001); WISC-III, Wechsler Intelligence Scale for Children—Third Edition (Wechsler, 1991); WISC-IV, Wechsler Intelligence Scale for Children—Fourth Edition (Wechsler, 2003); RIAS, Reynolds Intellectual Assessment Scales (Reynolds & Kamphaus, 2003); WRIT, Wide Range Intelligence Test (Glutting, Adams, & Sheslow, 2002); CAS, Cognitive Assessment System (Das & Naglieri, 1997); KAIT, Kaufman Adolescent and Adult Intelligence Test (Kaufman & Kaufman, 1993); DAS, Differential Ability Scales (Elliott, 1990).

adequately. Finally, the SB5 measures four CHC broad abilities (i.e., Gf, Gc, Gv, Gsm).

Table 9.3 shows that the WJ III continues to include measures of all the major broad cognitive abilities and now measures these abilities well, particularly when it is used in conjunction with the Diagnostic Supplement (DS; Woodcock, McGrew, Mather, & Schrank, 2003). Moreover, a comparison of Tables 9.1 and 9.3 indicates that two broad abilities not measured by many intelligence batteries prior to 1998 are now measured by the majority of intelligence batteries available today—that is, Gf and Gsm. These broad abilities may be better represented on revised and new intelligence batteries because of the accumulating research evidence regarding their importance in overall academic success (Flanagan et al., 2002). Finally, Table 9.3 reveals that intelligence batteries continue to fall short in their measurement of three CHC broad abilities—specifically, Glr, Ga, and Gs. Thus, although there is greater coverage of CHC broad abilities now than there was only a few years ago, the need for the CB approach to assessment remains.

In sum, the CHC theory and the cognitive ability classifications of the CB approach have had a major impact on intelligence test development in recent years. The creators of some tests used CHC theory and CB classifications as a blueprint, while the developers of others adhered more loosely to the theory. It seems clear that the new generation of intelligence batteries has been influenced substantially by

TABLE 9.3. Representation of Broad CHC Abilities on Eight Intelligence Batteries Published after 1998

Battery	Gf	Gc	Gv	Gsm	Glr	Ga	Gs
WISC-IV	Matrix Reasoning Picture Concepts Arithmetic	Vocabulary Information Similarities Comprehension Word Reasoning	Block Design Picture Completion	Digit Span Letter–Number Sequencing	—	—	Symbol Search Coding Cancellation
WAIS-III[a]	Matrix Reasoning	Vocabulary Information Similarities Comprehension	Block Design Object Assembly Picture Arrangement Picture Completion	Digit Span Letter–Number Sequencing	—	—	Symbol Search Digit–Symbol Coding
WPPSI-III	Matrix Reasoning Picture Concepts	Vocabulary Information Similarities Comprehension Receptive Vocabulary Picture Naming Word Reasoning	Block Design Object Assembly Picture Completion	—	—	—	Coding Symbol Search
KABC-II	Pattern Reasoning Story Completion	Expressive Vocabulary Verbal Knowledge Riddles	Triangles Gestalt Closure Rover Block Counting Conceptual Thinking Face Recognition	Number Recall Word Order Hand Movements	Atlantis Rebus Atlantis Delayed Rebus Delayed	—	—
WJ III/DS	Concept Formation Analysis–Synthesis	Verbal Comprehension General	Spatial Relations Picture Recognition	Memory for Words Numbers Reversed	Visual–Auditory Learning Retrieval Fluency	Sound Blending Auditory Attention Incomplete Words	Visual Matching Decision Speed Pair Cancellation

	Number Series Number Matrices	Information Bilingual Verbal Comprehension	Planning Visual Closure Block Rotation	Auditory Working Memory Memory for Sentences	Visual–Auditory Learning Delayed Rapid Picture Naming Memory for Names Memory for Names Delayed	Sound Pattern–Voice Sound Pattern–Music	Cross Out
SB5	Nonverbal Fluid Reasoning Verbal Fluid Reasoning Nonverbal Quantitative Reasoning Verbal Quantitative Reasoning	Nonverbal Knowledge Verbal Knowledge	Nonverbal Visual–Spatial Processing Verbal Visual–Spatial Processing	Nonverbal Working Memory Verbal Working Memory	—	—	—
RIAS	Odd-Item Out	Guess What Verbal Reasoning	What's Missing	Verbal Memory Nonverbal Memory	—	—	—
WRIT	Matrices	Verbal Analogies Vocabulary	Diamonds	—	—	—	—

Note. CHC classifications are based on the extant literature and primary sources such as Woodcock (1990), Horn (1991), Carroll (1993), McGrew (1997), McGrew and Flanagan (1998), Caltabiano and Flanagan (2004), and Keith, Fine, Taub, Reynolds, and Kranzler (2004). WISC-IV, Wechsler Intelligence Scale for Children—Fourth Edition (Wechsler, 2003); WAIS-III, Wechsler Adult Intelligence Scale—Third Edition (Wechsler, 1997); WPPSI-III, Wechsler Preschool and Primary Scale of Intelligence—Third Edition (Wechsler, 2002); KABC-II, Kaufman Assessment Battery for Children—Second Edition (Kaufman & Kaufman, 2004); WJ III, Woodcock–Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001); WJ III/DS, Diagnostic Supplement to the Woodcock–Johnson III Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2003); SB5, Stanford–Binet Intelligence Scales, Fifth Edition (Roid, 2003); RIAS, Reynolds Intellectual Assessment Scales (Reynolds & Kamphaus, 2003); WRIT, Wide Range Intelligence Test (Glutting et al., 2002).

[a]Although the WAIS-III was published in 1997, it is included in this table because its predecessor, the Wechsler Adult Intelligence Scale—Revised, was included in Table 9.1, and because we wished to present all revised Wechsler scales in one table.

CHC theory and its expansive research base. In addition, the CHC ability classifications of the CB approach have influenced test development and continue to play a role in narrowing the theory–practice gap.

IMPACT OF CHC THEORY AND THE CB APPROACH ON TEST INTERPRETATION

We believe that perhaps the greatest contribution that CHC theory and the CHC CB approach have made to psychoeducational assessment involves interpretation of ability test performance. In this section, we explain how and why we believe this to be true, through a brief discussion of the following topics: (1) limitations of using one cognitive or achievement battery to answer most referrals of suspected learning disability; (2) psychometrically defensible means of evaluating data across batteries; (3) systematic approach to organizing assessments, generating/testing hypotheses, and making interpretations; (4) application to an operational definition of learning disability; and (5) application of CB interpretive methods to current intelligence batteries.

Limitations of Single Test Batteries

As a result of the theoretical and empirical work of John Carroll, John Horn, Richard Woodcock, Kevin McGrew, Dawn Flanagan, Tim Keith, and numerous others, it became clear that no single intelligence battery adequately measured all the broad abilities delineated in CHC theory. That is, almost no intelligence battery, particularly the Wechsler scales, contained a sufficient number of tests to measure the breadth of broad CHC abilities. Many of the broad abilities not measured by the Wechsler scales or by some other batteries, such as Gf, Ga, and Glr, have demonstrated a significant relationship to academic achievement. Therefore, perhaps the greatest limitation of a single intelligence battery is related to the assessment of children referred for suspected learning disabilities. Most single intelligence batteries do not measure all of the abilities considered important for understanding learning difficulties (see Flanagan et al., 2002). The CB approach provides a systematic means of supplementing single intelligence batteries to ensure that the abilities considered most important vis-à-vis the referral are well represented in the assessment.

Psychometrically Defensible Means of Evaluating Data across Batteries

The CB approach provides a psychometrically defensible means of evaluating data within and across intelligence and achievement batteries. Following are some of the most salient ways in which the developers of the CB approach have made CHC-based assessment and interpretation across batteries defensible.

First, the CB approach provides professionals with a common, empirically based set of terms—in other words, a standard nomenclature that may be used to significantly reduce or eliminate miscommunication and misinterpretation within and across disciplines. This standard nomenclature also ensures that users of the CB approach will be less likely to make errors when combining cognitive or achievement tests (McGrew & Flanagan, 1998).

Second, the classification system of the CB approach is based on the results of theory-driven joint factor analyses and expert consensus studies. According to Kaufman (cited in Flanagan et al., 2000), the CB approach has current research at its foundation. It is based on sound theory and sound assessment principles.

Third, the use of the CB approach guards against two ubiquitous sources of invalidity in assessment—construct-irrelevant variance and construct underrepresentation (Messick, 1995). As stated earlier, the former source of invalidity is reduced or eliminated through the construction of broad-ability clusters, using the broad-ability classifications of the CB approach. The latter source of invalidity is reduced or eliminated through the construction of clusters that include tests measuring qualitatively different aspects of the broad ability following narrow-ability classifications. These procedures have been incorporated into the test use and interpretation procedures of two major intelligence batteries (the WISC-IV and KABC-II; Flanagan & Kaufman, 2004; Kaufman, Lichtenberger, Fletcher-Janzen, & Kaufman, in press). For a point–counterpoint discussion of the psychometric characteristics of the CB approach, see Watkins, Glutting, and Youngstrom (2002), Watkins, Youngstrom, and Glutting (2002), and Ortiz and Flanagan (2002a, 2002b).

Systematic Approach to Organizing Assessments, Generating/Testing Hypotheses, and Making Interpretations

The CB approach provides practitioners with the means to organize assessments, generate and test hypotheses regarding an individual's functioning, and draw reliable and valid conclusions from cross-battery data in a systematic manner. The CB approach to assessment, decision making, and interpretation "provides an advancement over traditional practice in terms of both measurement and meaning" (Flanagan & Ortiz, 2001, p. 84). Practitioners who are familiar with the CB approach know that it is based on hypothesis-driven assessment and interpretation, which include a priori and a posteriori assumptions as well as recursive assessment activities. Through the use of this method, practitioners are likely to become more confident in their approach to data collection and interpretation, as well as their ability to make placement and other educationally relevant decisions.

Application to an Operational Definition of Learning Disability

In 2002, Flanagan and colleagues extended the CB approach to include academic ability tests, for several reasons. First, the measurement and interpretation of academic abilities are rarely grounded in theory. Second, CHC theory includes academic ability constructs in its structure (e.g., Gq and Grw). Third, information derived from intelligence and achievement batteries is seldom integrated and interpreted systematically. Through the inclusion of CHC classifications of academic achievement tests, the CB approach could be readily applied to the process of evaluating individuals with learning difficulties.

Flanagan and colleagues (2002) integrated CB interpretation guidelines, current CHC theory and research (including findings regarding the relations between cognitive and academic abilities), and recent research and developments in the field of learning disabilities, to conceptualize an operational definition of learning disabilities. This definition includes several levels of assessment and evaluation, each containing specific criteria that must be met before advancing to subsequent levels. Flanagan and colleagues suggest following this operational definition after an individual has not responded positively to appropriately designed and monitored interventions. It is only when criteria at all levels of the operational definition have been met that an individual may be diagnosed with a learning disability. Individuals who meet all criteria are characterized as having a below-average aptitude–achievement consistency (i.e., related cognitive and academic deficits) within an otherwise normal ability profile (i.e., intact abilities). Furthermore, the deficits are judged to be intrinsic to the individual, as opposed to being caused primarily by exclusionary factors (e.g., cultural differences, language differences, emotional disturbance, etc.). For a comprehensive description of this operational definition, see Mascolo and Flanagan (Chapter 24, this volume).

Application of CB Interpretive Methods to Current Intelligence Batteries

Kaufman and Kaufman, the authors of the KABC-II—the newest intelligence test in the field—have incorporated CB methods into their comprehensive interpretive approach (Kaufman & Kaufman, 2004; Kaufman et al., in press). For example, they place greater emphasis on normative (as opposed to ipsative) strengths and weaknesses; they have eliminated individual subtest analysis, focusing only on scale- or cluster-level interpretation; and they recommend interpreting only those abilities that are unitary (i.e., abilities defined by nonsignificant variations among the test scores that represent them). Similarly, CB interpretive procedures have been applied to the WISC-IV (Flanagan & Kaufman, 2004). In short, the leader of *intelligent* test interpretation, Alan S. Kaufman, has integrated his methods with the CB methods in an effort to advance the science of interpreting cognitive abilities.

CONCLUSIONS AND FUTURE DIRECTIONS

CHC theory and the CB approach have influenced intelligence test development and interpretation. The new millennium has brought with it a new generation of intelligence tests. For the first time in the history of intelligence test development, theory has played a prominent role. The latest editions of the WJ, SB, and K-ABC are firmly grounded in CHC theory. The latest edition of the WISC represents the most significant revision of any Wechsler scale to date. Although not overtly based on any specific theory, the WISC-IV is more closely aligned with theory than previous editions and may be interpreted from the perspective of CHC theory (Flanagan & Kaufman, 2004). The CB approach may be used to operationalize CHC theory more fully by supplementing any single intelligence battery with relevant tests from other batteries. It seems clear that our current instrumentation and interpretive methods will serve to improve upon the practice of intellectual assessment.

The future of intelligence test development and interpretation will undoubtedly be influenced by CHC theory and research for many years to come. The findings of current research have already suggested the need to revise and refine the theory (Horn & Blankson, Chapter 3, this volume; McGrew, Chapter 8, this volume). Findings in the learning disabilities literature, as they relate to the abilities and processes most closely associated with academic skills, suggest that there is a need to represent *narrow* abilities more comprehensively on intelligence and achievement batteries.

Future research will probably continue to examine the importance of specific cognitive abilities in the explanation of academic outcomes, above and beyond the variance explained by *g*. Also, it is hoped that future research in the field of learning disabilities will be guided by CHC theory, and that the search for aptitude–achievement interactions will be revisited using CHC constructs as opposed to Wechsler's traditional clinical composites (i.e., Verbal and Performance IQs). In general, the infusion of CHC theory in related fields, such as learning disabilities, education, and neuropsychology, seems necessary to elucidate the utility of cognitive ability assessment in the design of educational treatment plans and interventions for individuals with learning difficulties.

NOTE

1. John Carroll's contribution to the first edition of this volume has been reprinted for this edition.

REFERENCES

Caltabiano, L., & Flanagan, D. P. (2004). *Content validity of new and recently revised intelligence tests: Implications for interpretation*. Manuscript in preparation.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge, England: Cambridge University Press.

Cattell, R. B. (1957). *Personality and motivation structure and measurement*. Yonkers, NY: World Book.

Cattell, R. B. (1971). *Abilities: Their structure, growth, and action*. Boston: Houghton Mifflin.

Daniel, M. H. (1997). Intelligence testing: Status and trends. *American Psychologist, 52,* 1038–1045.

Das, J. P., & Naglieri, J. A. (1997). *Das–Naglieri Cognitive Assessment System*. Itasca, IL: Riverside.

Elliott, C. D. (1990). *Differential Ability Scales*. San Antonio, TX: Psychological Corp.

Flanagan, D. P., & Kaufman, A. S. (2004). *Essentials of WISC-IV assessment*. New York: Wiley.

Flanagan, D. P., & McGrew, K. S. (1997). A cross-battery approach to assessing and interpreting cognitive abilities: Narrowing the gap between practice and cognitive science. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 314–325). New York: Guilford Press.

Flanagan, D. P., McGrew, K. S., & Ortiz, S. O. (2000). *The Wechsler intelligence scales and Gf-Gc theory: A contemporary approach to interpretation.* Needham Heights, MA: Allyn & Bacon.

Flanagan, D. P., & Ortiz, S. O. (2001). *Essentials of cross-battery assessment.* New York: Wiley.

Flanagan, D. P., Ortiz, S. O., Alfonso, V. C., & Mascolo, J. T. (2002). *The achievement test desk reference (ADTR): Comprehensive assessment and learning disabilities*. Boston: Allyn & Bacon.

Glutting, J. J., Adams, W., & Sheslow, D. (2002). *Wide Range Intelligence Test*. Wilmington, DE: Wide Range.

Glutting, J. J., Watkins, M. M., & Youngstrom, E. A. (2003). Multifactored and cross-battery ability assessments: Are they worth the effort? In C. R. Reynolds & R. W. Kamphaus (Eds.), *Handbook of psychological and educational assessment of chil-*

dren: Intelligence, aptitude, and achievement (2nd ed., pp. 343–377). New York: Guilford Press.

Horn, J. L. (1965). *Fluid and crystallized intelligence: A factor analytic and developmental study of the structure among primary mental abilities*. Unpublished doctoral dissertation, University of Illinois, Champaign.

Horn, J. L. (1968). Organization of abilities and the development of intelligence. *Psychological Review, 75,* 242–259.

Horn, J. L. (1991). Measurement of intellectual capabilities: A review of theory. In K. S. McGrew, J. K. Werder, & R. W. Woodcock, *WJ-R technical manual* (pp. 197–232). Chicago: Riverside.

Horn, J. L., & Stankov, L. (1982). Auditory and visual factors of intelligence. *Intelligence, 6,* 165–185.

Kaufman, A. S., & Kaufman, N. L. (1983). *Kaufman Assessment Battery for Children*. Circle Pines, MN: American Guidance Service.

Kaufman, A. S., & Kaufman, N. L. (1993). *Kaufman Adolescent and Adult Intelligence Test*. Circle Pines, MN: American Guidance Service.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman Assessment Battery for Children—Second Edition*. Circle Pines, MN: American Guidance Service.

Kaufman, A. S., Lichtenberger, E. O., Fletcher-Janzen, E., & Kaufman, N. L. (in press). *Essentials of KABC-II assessment*. New York: Wiley.

Keith, T. Z. (1997). Using confirmatory factor analysis to aid in understanding the constructs measured by intelligence tests. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 373–402). New York: Guilford Press.

Keith, T. Z., Fine, J. G., Taub, G. E., Reynolds, M. R., & Kranzler, J. H. (2004). *Hierarchical, multi-sample, confirmatory factor analysis of the Wechsler Intelligence Scale for Children—Fourth Edition: What does it measure?* Manuscript submitted for publication.

Keith, T. Z., Kranzler, J. H., & Flanagan, D. P. (2001). Independent confirmatory factor analysis of the Cognitive Assessment System (CAS): What does the CAS measure? *School Psychology Review, 28,* 117–144.

McGrew, K. S. (1997). Analysis of the major intelligence batteries according to a proposed comprehensive Gf-Gc framework. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 151–180). New York: Guilford Press.

McGrew, K. S., & Flanagan, D. P. (1998). *The intelsligence test desk reference (ITDR):* Gf-Gc *cross-battery assessment*. Boston: Allyn & Bacon.

McGrew, K. S., Flanagan, D. P., Keith, T. Z., & Vanderwood, M. (1997). Beyond *g*: The impact of Gf-Gc specific cognitive abilities research on the future use and interpretation of intelligence tests in the schools. *School Psychology Review, 26,* 177–189.

Messick, S. (1989). Validity. In R. Linn (Ed.), *Educational measurement* (3rd ed., pp. 13–103). Washington, DC: American Council on Education.

Messick, S. (1995). Validity of psychological assessment: Validation of inferences from persons' responses and performances as scientific inquiry into score meaning. In A. E. Kazdin (Ed.), *Methodological issues and strategies in clinical research* (2nd ed., pp. 241–261). Washington, DC: American Psychological Association.

Neisser, U., Boodoo, G., Bouchard, T. J., Boykin, A. W., Brody, N., Ceci, S. J., et al. (1996). Intelligence: Knowns and unknowns. *American Psychologist, 51,* 77–101.

Ortiz, S. O., & Flanagan, D. P. (2002a, May). Cross-battery assessment revisited: Some cautions concerning "some cautions" (Part I). *Communique, 30*(7), 32–34.

Ortiz, S. O., & Flanagan, D. P. (2002b, June). Some cautions concerning "Some cautions concerning cross-battery assessment" (Part II). *Communique, 30*(8), 36–38.

Phelps, L., McGrew, K. S., Knopik, S. N., & Ford, L. (in press). The general (*g*) broad and narrow CHC stratum characteristics of the WJ III and WISC-III tests: A confirmatory cross-battery investigation. *School Psychology Quarterly.*

Reynolds, C. R.-, & Kamphaus, R. W. (2003). *Reynolds Intellectual Assessment Scales*. Lutz, FL: Psychological Assessment Resources.

Roid, G. H. (2003). *Stanford–Binet Intelligence Scales, Fifth Edition*. Itasca, IL: Riverside.

Spearman, C. E. (1927). *The abilities of man*. London: Macmillan.

Sternberg, R. J., & Kaufman, J. C. (1998). Human abilities. *Annual Review of Psychology, 49,* 479–502.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1986). *Stanford–Binet Intelligence Scale: Fourth Edition*. Chicago: Riverside.

Vanderwood, M. L, McGrew K. S., Flanagan, D. P., & Keith, T. Z. (2001). The contribution of general and specific cognitive abilities to reading achievement. *Learning and Individual Differences, 13*, 159–188.

Watkins, M. W., Glutting, J. J., & Youngstrom, E. A. (2002, October). Cross-battery assessment: Still concerned. *Communique, 31*(2), 42–44.

Watkins, M. W., Youngstrom, E. A., & Glutting, J. J. (2002, February). Some cautions concerning cross-battery assessment. *Communique, 30*(5), 16–20.

Wechsler, D. (1981). *Wechsler Adult Intelligence Scale—Revised*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (1989). *Wechsler Preschool and Primary Scale of Intelligence—Revised*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children—Revised*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale—Third Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2002). *Wechsler Preschool and Primary Scale of Intelligence—Third Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children—Fourth Edition*. San Antonio, TX: Psychological Corporation.

Woodcock, R. W. (1990). Theoretical foundations of the WJ-R measures of cognitive ability. *Journal of Psychoeducational Assessment, 8,* 231–258.

Woodcock, R. W. (1994). Measures of fluid and crystallized intelligence. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 452–456). New York: Macmillan.

Woodcock, R. W., & Johnson, M. B. (1989). *Woodcock–Johnson Psycho-Educational Battery—Revised*. Chicago: Riverside.

Woodcock, R. W., McGrew, K. S., & Mather N. (2001). *Woodcock–Johnson III Tests of Cognitive Abilities*. Itasca, IL: Riverside.

Woodcock, R. W., McGrew, K. S., Mather, N., & Schrank, F. A. (2003). *Diagnostic Supplement to the Woodcock–Johnson III Tests of Cognitive Abilities*. Itasca, IL: Riverside.