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CHAPTER 9

Analysis of the Major Intelligence Batteries According to a Proposed Comprehensive Gf-Gc Framework

KEVIN S. McGREW

SIGNIFICANT PROGRESS has been made during the past 60 to 70 years in understanding the structure of human intelligence. More important, this knowledge is now beginning to influence the development and interpretation of psychoeducational assessment instruments.

I predict that this progress has been particularly energized by the publication of *Human cognitive abilities: A survey of factor-analytic studies* by John Carroll (1993). Carroll summarizes his review and reanalysis of more than 460 different data sets that included nearly all the more important and classic factor analytic studies of human cognitive abilities. On the book cover, Richard Snow states that "John Carroll has done a magnificent thing. He has reviewed and reanalyzed the world's literature on individual differences in cognitive abilities . . . no one else could have done it . . . it defines the taxonomy of cognitive differential psychology for many years to come." Burns (1994) was similarly impressed when he stated that Carroll's book "is simply the finest work of research and scholarship I have read and is destined to be *the classic study and reference work* on human abilities for decades to come" (p. 35).

Simply put, all scholars, test developers, and users of intelligence tests need to become familiar with Carroll's treatise on the factors of human abilities. Unfortunately, this is a daunting task. Each of Carroll's chapters is a major literature review in a specific cognitive domain (Burns, 1994). The book is lengthy and, for those not well versed in the language and literature of factor analysis of cognitive variables, a challenge to read.

The purpose of this chapter is to facilitate the infusion of this important knowledge into psychoeducational assessment practice. My goal is to advocate for Carroll's suggestion (Chapter 7, this volume) that clinicians use his "map" of known cognitive abilities to guide their selection and interpretation of tests in intelligence batteries. Further, my goal further is to provide a "bridge" between the theoretical and empirical research on the factors of intelligence and the development and interpretation of psychoeducational assessment batteries.

CARROLL'S THREE-STRATUM MODEL

Carroll has proposed a three-tier model of human cognitive abilities that differentiates abilities as a function of breadth. At the broadest level (stratum III) is a *general* intelligence factor conceptually similar to Spearman's and Vernon's *g*. Next in breadth are eight *broad* abilities that represent "basic constitutional and long-standing characteristics of individuals that can govern or influence a great variety of behaviors in a given domain" (Carroll, 1993, p. 634). Stratum level II includes the abilities of Fluid Intelligence, Crystallized Intelligence, General Memory and Learning, Broad Visual Perception, Broad Auditory Perception, Broad Retrieval Ability, Broad Cognitive Speediness, and Reaction Time/Decision Speed. Finally, stratum level I includes 69 *narrow* abilities that are subsumed by the stratum II abilities, which in turn are subsumed by the single stratum III *g* factor. Carroll's work in this volume provides a detailed treatment of his model.

THE HORN–CATTELL Gf-Gc MODEL

After reviewing the major historical and contemporary theories and models of intelligence, Carroll concludes that the Horn–Cattell Gf-Gc model is the closest approximation to his three-stratum level model. Carroll states that the Horn–Cattell Gf-Gc model "appears to offer the most well-founded and reasonable approach to an acceptable theory of the structure of cognitive abilities" (Carroll, 1993, p. 62).

Horn (1991) has extended the work of Cattell (1941) by identifying 9 to 10 broad Gf-Gc abilities: Fluid Intelligence, Crystallized Intelligence, Short-Term Acquisition and Retrieval, Visual Intelligence, Auditory Intelligence, Long-Term Storage and Retrieval, Cognitive Processing Speed, Correct Decision Speed, and Quantitative Knowledge. A "newcomer" factor vying for inclusion in the Horn–Cattell Gf-Gc model is associated with the comprehension and expression of reading and writing skills (Grw) (Horn, 1988; McGrew, Werder, & Woodcock, 1991; Woodcock, 1993, in press). A thorough treatment of the Horn–Cattell Gf-Gc model is presented by Horn and Noll (Chapter 4, this volume).

A SYNTHESIZED CARROLL AND HORN–CATTELL Gf-Gc FRAMEWORK

There are strong similarities between the Carroll and Horn–Cattell models. Both include the similarly defined broad abilities of fluid (Gf) and crystallized (Gc) intelligence, short-term memory (i.e., General Memory and Learning and Short-Term Acquisition and Retrieval—Gsm), visual (Gv) and auditory (Ga) processing or intelligence, storage and retrieval (i.e., Broad Retrieval Ability and Long-Term Associative Storage and Retrieval—Glr), and two speed abilities (i.e., Broad Cognitive Speediness or Cognitive Processing Speed—Gs, and Reaction Time/Decision Speed or Correct Decision Speed—Gt).

The most obvious difference between the two models is the presence or absence of a higher-order *g* factor in Carroll's and Horn's models, respectively. A careful reading of Carroll's and Horn's writings reflect other differences in the placement of narrow factors under the broad factors. The most salient differences are (1) the inclusion of reading and writing abilities under crystallized intelligence (Carroll) versus their existence under a separate broad reading and writing (Grw) ability (Horn–Cattell), (2) the inclusion of quantitative abilities under fluid intelligence (Carroll) versus their placement under a separate broad quantitative (Gq) ability (Horn–Cattell), and (3) and the inclusion of phonological awareness (e.g., phonetic coding) under crystallized intelligence (Carroll) versus broad auditory intelligence or perception (Ga) (Horn–Cattell).

Finally, Carroll includes short-term memory abilities and associative, meaningful, and free recall memory abilities together with learning abilities under a General Memory and Learning factor. In contrast, Horn (1991) makes a distinction between immediate apprehension (e.g, short-term memory span) and storage and retrieval abilities. Carroll includes both classes of memory abilities under a single factor. Horn indicates that it is often difficult to distinguish short-term memory and storage and retrieval abilities (Horn, 1988). Although he has included associative memory under short-term memory (Horn, 1994), Horn (1988) has also mentioned measures of associative memory (e.g., the Woodcock-Johnson Tests of Cognitive Ability—Revised [WJ-R COG] Delayed Recall tests) as clear measures of long-term storage and retrieval abilities (Glr) (Horn, 1988). Both Carroll and Horn place the fluency abilities (i.e., naming facility and word fluency) under their respective retrieval factors.

Before attempting to classify the individual tests from the major intelligence batteries according to a synthesized Carroll and Horn perspective, I felt that it was important to first resolve (at least to my satisfaction) the most notable differences between the Carroll and Horn–Cattell models. Using 37 measures from the standardization sample of the complete WJ-R battery, I used confirmatory factor analysis procedures to test a number of alternative models that operationalized the Carroll and Horn–Cattell model differences (see Appendix and Table 9.10 in this chapter for a brief description and summary of the results). The WJ-R battery is particularly well suited to a comparison of the Carroll and Horn model differences, as evidenced by Bickley, Keith, and Wolfes's (1995) use of the WJ-R norm data to evaluate the stability of Carroll's model across the lifespan. The specified models benefited from information provided by a separate analysis of the complete WJ-R by Carroll with the same factoring procedures he used in his massive review (see Appendix and Table 9.11 in this chapter for Carroll's results).

From these analyses, I conclude that a feasible framework would be one that (1) retains a quantitative reasoning/knowledge factor (Gq) distinct from fluid intelligence (Gf), (2) places reading and writing abilities under a separate broad reading and writing factor (Grw), (3) places phonological awareness abilities under auditory processing or intelligence (Ga), and (4) retains short-term memory abilities under a separate broad ability (Gsm) and places storage and retrieval abilities (e.g., associative memory) under a broad retrieval (Glr) ability. No attempt was made to resolve the existence of a *g* factor, a long-standing theoretical debate that does not bear directly on the purpose of this chapter.

As a result, the comprehensive Gf-Gc framework presented in Figure 9.1 was used to structure the remainder of my analyses. Using this framework, I then placed most of the first-order narrow ability factors summarized by Carroll under the 10 broad Gf-Gc abilities. Brief definitions of each of these abilities are presented in Table 9.1.[1]

THE Gf-Gc CLASSIFICATION OF TESTS IN INTELLIGENCE BATTERIES

Armed with the framework and the narrow ability definitions, I classified the individual tests in the Differential Ability Scales (DAS; Elliott, 1990), the Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983), the Kaufman Adolescent and Adult Intelligence Test (KAIT; Kaufman & Kaufman, 1993), the Stanford-Binet Intelligence Scale: Fourth Edition (SB-IV; Thorndike, Hagen, & Sattler, 1986), the three Wechsler Batteries (Wechsler, 1981, 1989, 1991), and the Woodcock-Johnson Psycho-Educational Battery—Revised (WJ-R; Woodcock & Johnson,

1989) at the narrow ability level. The Das–Naglieri Cognitive Assessment System (DN:CAS; Das, Naglieri, & Kirby, 1994) was not included as it was only in the development stages at the time I conducted these analyses.

The classification of each individual test as a measure of one or more of the narrow and/or broad Gf-Gc abilities was guided by a review of results of joint confirmatory factor analysis studies conceptualized from the modern Gf-Gc framework (not the older and simpler Gf-Gc dichotomy). The primary studies were those of Flanagan and McGrew (1995), McGhee (1993), and Woodcock (1990). Woodcock's (1990) comprehensive synthesis of a series of joint confirmatory factor studies was the cornerstone of my broad Gf-Gc test classifications for the WJ-R, K-ABC, SB-IV, and Wechsler batteries (researchers are encouraged to read Woodcock's article to gain an appreciation for the significance of his work and why it played such a pivotal role in my classifications). McGhee's (1993) study was the primary source of the DAS test classifications because it was the only study to include this instrument in a Gf-Gc–based confirmatory factor analysis. Flanagan and McGrew's (1995) Gf-Gc–based confirmatory factor study provided the primary classification information for the KAIT tests. The McGhee (1993) and Flanagan and McGrew (1995) studies are important because they used the modern Gf-Gc framework for their confirmatory factor analyses and they used tests from the WJ-R, two design features that provided a link with Woodcock's analyses. All three sources (Flanagan & McGrew, 1995; McGhee, 1993; Woodcock, 1990) were linked through the use of the WJ-R as Gf-Gc marker tests and the use of a common Gf-Gc confirmatory factor analysis framework. Although the primary contribution of the McGhee (1993) and Flanagan and McGrew (1995) studies is the provision of information about the DAS and KAIT tests, these studies also supported or clarified Woodcock's (1990) WJ-R test classifications.

Woodcock's empirically based criteria for classifying tests as strong, moderate, or mixed measures of Gf-Gc factors were the primary basis for my broad Gf-Gc classifications. If a test was classified as a strong or moderate Gf-Gc measure and it showed no other secondary loadings (was not found to be a factorially complex test), the broad Gf-Gc classifications implied by these findings were accepted. For example, the WJ-R Visual–Auditory Learning test was classified by Woodcock (1990) as a strong measure of Glr based on a median factor loading of .697 across 14 different analyses. Another example of a clear classification was the SB-IV Vocabulary test as a strong measure of Gc, based on a median factor loading of .810 across four analyses. Broad Gf-Gc factor classifications for tests with such consistent strong or moderate factor loadings across analyses were made with relative ease. Tests that showed evidence of measuring more than one broad Gf-Gc ability were classified accordingly. For example, across 15 different analyses, the WJ-R Memory for Sentences test displayed median factor loadings of .335 (Gc) and .554 (Gsm) (Woodcock, 1990). Thus, the WJ-R Memory for Sentences test was classified as an indicator of both Gc and Gsm.

In most cases the broad Gf-Gc test classifications provided by Woodcock (1990), or those classifications based on the application of the same criteria and logic to the McGhee (1993) or Flanagan and McGrew's (1995) studies, were made with little difficulty. However, this was not always the case. For example, Woodcock's (1990) analyses suggested that the WJ-R Picture Recognition test should be classified as a mixed measure of Gv (median loading of .378) and Glr (median loading of .248). McGhee's (1993) analyses found this test to have a relatively low, but significant, loading of .156 on a short-term (Gsm) visual memory factor. More important, when the Picture Recognition test was jointly analyzed with the KAIT tests, it formed a robust visual memory factor with the KAIT Memory for Block Designs test, with a factor loading in the .90s (Flanagan & McGrew, 1995). Flanagan and McGrew's results suggested that Woodcock's classification for this test may need modification, especially in light of the fact that none of the joint confirmatory factor studies he reported included other tests that might measure visual memory abilities. Thus, the Flanagan and McGrew results suggested that Woodcock's classification of this test should be modified. Because Flanagan and McGrew's (1995) results represented only one study, and Woodcock's Picture Recog-

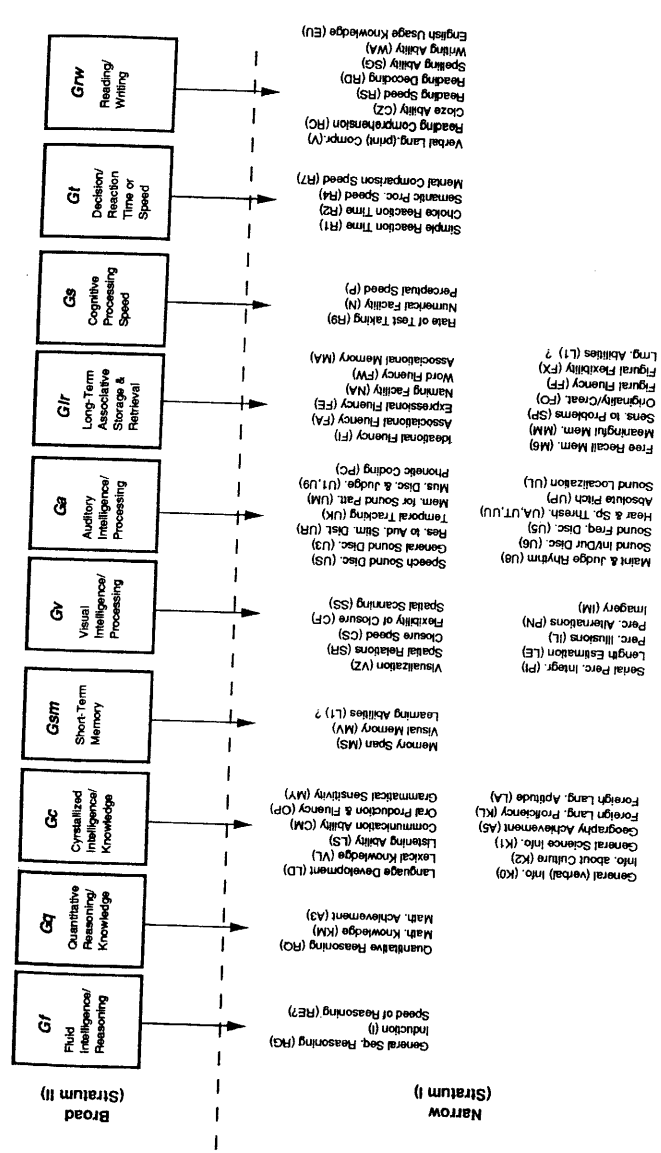

FIGURE 9.1. A proposed comprehensive Gf-Gc framework relevant to the interpretation of psychoeducational assessment batteries.

TABLE 9.1. First-Order Gf-Gc Narrow Stratum Level I Ability Definitions

Narrow stratum level I name (code)	Gf-Gc Broad Stratum Level II Ability Definition
	Fluid Intelligence/Reasoning (Gf)
General Sequential Reasoning (Seq Reas: 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 (Ind: I)	Ability to discover the underlying characteristic (e.g., rule, concept, process, trend, class membership) that governs a problem or a set of materials
Piagetian Reasoning (RP)	Seriation, conservation, classification and other cognitive abilities as defined by Piaget
Speed of Reasoning (RE)	(Not clearly defined by existing research)
	Quantitative Reasoning/Knowledge (Gq)
Quantitative Reasoning (Quan Reas: RQ)	Ability to inductively and deductively reason with concepts involving mathematical relations and properties
Mathematical Knowledge (Math Know: KM)	Range of general knowledge about mathematics
Mathematical Achievement (Math Ach: A3)	Measured mathematics achievement
	Crystallized Intelligence/Knowledge (Gc)
Language Development (Lng Dev: LD)	General development, or the understanding of words, sentences, and paragraphs (*not* requiring reading), in spoken native language skills
Lexical Knowledge (Lex Know: VL)	Extent of vocabulary that can be understood in terms of correct word meanings
Listening Ability (Lst Abl: LS)	Ability to listen and comprehend oral communications
General (verbal) Information (Gnrl Info: KO)	Range of general knowledge
Information about Culture (Info Cltr: K2)	Range of cultural knowledge (e.g., music, art)
General Science Information (Sci Info: K1)	Range of scientific knowledge (e.g., biology, physics, engineering, mechanics, electronics)
Geography Achievement (Geo Ach: A5)	Range of geography knowledge
Communication Ability (CM)	Ability to speak in "real life" situations (e.g., lecture, group participation) in an adult-like manner
Oral Production and Fluency (OP)	More specific or narrow oral communication skills than reflected by Communication Ability (CM)
Grammatical Sensitivity (MY)	Knowledge or awareness of the grammatical features of the native language
Foreign Language Proficiency (KL)	Similar to LD but for a foreign language
Foreign Language Aptitude (LA)	Rate and ease of learning a new language
	Short-Term Memory (Gsm)
Memory Span (Mem Span: MS)	Ability to attend to and immediately recall temporally ordered elements in the correct order after a single presentation

TABLE 9.1. (*Cont.*)

Narrow stratum level I name (code)	Gf-Gc Broad Stratum Level II Ability Definition
	Short-Term Memory (Gsm) (*cont.*)
Visual Memory (Vis Mem: MV)	Ability to form and store a mental representation or image of a visual stimulus and then recognize or recall it later
Learning Abilities (L1) (also listed under Glr)	(Not clearly defined by existing research)
	Visual Intelligence/Processing (Gv)
Visualization (Vis: VZ)	Ability to mentally manipulate objects or visual patterns and to "see" how they would appear under altered conditions
Spatial Relations (Spt Rel: SR)	Ability to rapidly perceive and manipulate visual patterns or to maintain orientation with respect to objects in space
Closure Speed (Cls Spd: 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
Flexibility of Closure (Flex Cls: CF)	Ability to identify a visual figure or pattern embedded in a complex visual array, *when knowing in advance* what the pattern is
Spatial Scanning (Spt Scan: SS)	Ability to accurately and quickly survey a spatial field or pattern and identify a path through the visual field or pattern
Serial Perceptual Integration (SerP Int: PI)	Ability to identify a pictorial or visual pattern when parts of the pattern are presented rapidly in order
Length Estimation (LE)	Ability to accurately estimate or compare visual lengths and distances without using measurement instruments
Perceptual Illusions (IL)	Ability to resist being affected by perceptual illusions involving geometric figures
Perceptual Alternations (PN)	Consistency in the rate of alternating between different visual perceptions
Imagery (IM)	Ability to vividly mentally manipulate abstract spatial forms (not clearly defined by existing research)
	Auditory Intelligence/Processing (Ga)
Phonetic Coding (Phn Cod: PC)	Ability to process speech sounds, as in identifying, isolating, and blending sounds; phonological awareness
Speech Sound Discrimination (SpSd Disc: US)	Ability to detect differences in speech sounds under conditions of little distraction or distortion
Resistance to Auditory Stimulus Distortion (Res AdDS: UR)	Ability to understand speech and language that has been distorted or masked in one or more ways
Memory for Sound Patterns (Mem Sndp: UM)	Ability to retain on a short-term basis auditory events such as tones, tonal patterns, and voices
General Sound Discrimination (U3)	Ability to discriminate tones, tone patterns, or musical materials with regard to pitch, intensity, duration, and rhythm
Temporal Tracking (UK)	Ability to track auditory temporal events so as to be able to count or rearrange them
Musical Discrimination and Judgment (U1, U9)	Ability to discriminate and judge tonal patterns in music with respect to phrasing, tempo, and intensity variations

(*cont.*)

TABLE 9.1. (*Cont.*)

Narrow stratum level I name (code)	Definition
	Gf-Gc Broad Stratum Level II Ability
	Auditory Intelligence Processing (Ga) (*cont.*)
Maintaining and Judging Rhythm (U8)	Ability to recognize and maintain a musical beat.
Sound-Intensity/Duration Discrimination (U6)	Ability to discriminate sound intensities and to be sensitive to the temporal/rhythmic aspects of tonal patterns
Sound-Frequency Discrimination (U5)	Ability to discriminate frequency attributes (pitch and timbre) of tones
Hearing and Speech Threshold factors (UA, UT, UU)	Ability to hear pitch and varying sound frequencies
Absolute Pitch (UP)	Ability to perfectly identify the pitch of tones
Sound Localization (UL)	Ability to localize heard sounds in space
	Long-Term Associative Storage and Retrieval (Glr)
Associative Memory (Assc Mem: 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)
Meaningful Memory (Mng Mem: MM)	Ability to recall a set of items where there is a meaningful relation between items or the items comprise a meaningful story or connected discourse
Free Recall Memory (FrRe Mem: M6)	Ability to recall as many unrelated items as possible, in any order, after a large collection of items is presented
Ideational Fluency (FI)	Ability to rapidly produce a series of ideas, words, or phrases related to a specific condition or object
Associational Fluency (FA)	Ability to rapidly produce words or phrases associated in meaning (semantically associated) with a given word or concept
Expressional Fluency (FE)	Ability to rapidly think of and organize words or phrases into meaningful complex ideas
Naming Facility (NA)	Ability to rapidly produce names for concepts
Word Fluency (FW)	Ability to rapidly produce words that have specific phonemic, structural, or orthographic characteristics
Figural Fluency (FF)	Ability to rapidly draw or sketch several examples or elaborations when given a starting visual stimulus
Figural Flexibility (FX)	Ability to change set in order to generate new and different solutions to figural problems
Sensitivity to Problems (SP)	Ability to rapidly think of solutions to practical problems
Originality/Creativity (FO)	Ability to rapidly produce original, clever, or uncommon responses to specified tasks
Learning Abilities (L1)	[Also listed under Gsm] (Not clearly defined by existing research)
	Cognitive Processing Speed (Gs)
Perceptual Speed (Prc Spd: P)	Ability to rapidly search for and compare visual symbols presented side by side or separated in a visual field
Rate-of-Test-Taking (Rate TsTk: R9)	Ability to rapidly perform tests which are relatively easy or that require very simple decisions

TABLE 9.1. (*Cont.*)

Narrow stratum level I name (code)	Definition
	Gf-Gc Broad Stratum Level II Ability
	Cognitive Processing Speed (Gs) (*cont.*)
Number Facility (N)	Ability to rapidly and accurately manipulate and deal with numbers, from elementary skills of counting and recognizing numbers to advanced skills of adding, subtracting, multiplying, and dividing numbers
	Decision/Reaction Time or Speed (Gt)
Simple Reaction Time (R1)	Reaction time to the presentation of a single stimulus
Choice Reaction Time (R2)	Reaction time to one of two or more alternative stimuli, depending on which alternative is signaled
Semantic Processing Speed (R4)	Reaction time when the decision requires some encoding and mental manipulation of stimulus content
Mental Comparison Speed (R7)	Reaction time where the stimuli must be compared for a particular attribute
	Reading/Writing (Grw)
Reading Decoding (Rdg Dec: RD)	Ability to recognize and decode words or pseudowords in reading
Reading Comprehension (Rdg Cmp: RC)	Ability to comprehend connected discourse during reading
Verbal (printed) Language Comprehension (Vrbl Cmp: V)	General development, or the understanding of words, sentences, and paragraphs in native language, as measured by *reading* vocabulary and *reading* comprehension tests
Cloze Ability (Clz Abl: CZ)	Ability to supply words deleted from prose passages that must be read
Spelling Ability (Spl Abl: SG)	Ability to spell (not clearly defined by existing research)
Writing Ability (Wrt Abl: WA)	Ability to write with clarity of thought, organization, and good sentence structure (not clearly defined by existing research)
English Usage Knowledge (Eng UsKn: EU)	Knowledge of writing in the English language with respect to capitalization, punctuation, usage, and spelling
Reading Speed (RS)	Time required to silently read a passage as quickly as possible

Note. Most of the definitions were derived from *Human Cognitive Abilities: A Survey of Factor-Analytic Studies*, by J. B. Carroll, 1993. New York: Cambridge University Press. Copyright 1993 by Cambridge University Press. Two-letter factor codes (e.g., RG) are from Carroll (1993). Factor label abbreviations are those of the author and correspond to factor names used in Tables 9.2 through 9.8.

nition classification was based on 12 different analyses, radical changes were not made to Woodcock's initial classification. The Picture Recognition test was not simply classified as a measure of Gsm based on the Flanagan and McGrew study. Their findings, together with logical task analysis of the test, resulted in the WJ-R Picture Recognition test being classified as an indicator of Gsm, Gv, and Glr. There were other such modifications made to the classifications of Woodcock, but they all cannot be described in detail in this chapter. The above example illustrates the logic used when modifications were made to Woodcock's primary Gf-Gc test classifications.

Once the broad Gf-Gc test classifications were made based on the synthesis of the empirical studies of Flanagan and McGrew (1995), McGhee (1993), and Woodcock (1990), I asked 10 scholars with experience in the development and/or interpretation of intelligence tests for assistance in verifying these classifications and, more important, extending the classifications to the narrow ability level.[2] These individuals were asked to logically classify the tests contained in one or more of the intelligence batteries according to the narrow ability factor definitions (see Table 9.1). For each test in the battery they reviewed, they were asked to indicate the primary ability (based on the narrow ability definitions provided) measured by the test by giving the ability a rating of "1." If they felt that they could not discriminate between two major abilities measured by the test, they were instructed to give each a rating of "1." If the experts felt that the test measured a secondary ability (to a lesser degree than the primary ability), they were instructed to record a rating of "2." The individuals were requested to focus on the primary abilities measured by each test, not unique or specific abilities. Two or three individuals independently completed the task for each test. These ratings, together with my blind ratings of the same tests, were then summarized.

In most cases the expert ratings were consistent and reinforced the broad Gf-Gc factor classifications. The most important result from this expert consensus process was the classification of each test at the narrow ability level. Although no interrater reliability figures were calculated, the independent narrow ability classifications were typically consistent across individuals. When noticeable differences were observed, I made a decision based on a detailed review of Carroll's narrow ability definitions and my task analysis of the test. Thus, the narrow ability test classifications presented in this chapter are based primarily on an expert consensus process.

SUMMARY OF Gf-Gc TEST CLASSIFICATIONS

The classification summaries for the individual test batteries are presented in Tables 9.2 through 9.8. The amount of information is extensive and cannot be discussed in detail in a single chapter. Thus, I will only make general comments that should allow readers the ability to pursue the information desired in the tables.

Breadth of Gf-Gc Coverage by Intelligence Batteries

As would be expected given its theoretical grounding in the Horn–Cattell Gf-Gc model, the WJ-R battery (Tables 9.7 and 9.8) provides for the broadest coverage of the Gf-Gc abilities used in this analysis. The only broad Gf-Gc ability not represented by at least one narrow ability test in the WJ-R, which was also not present in any of the other batteries, is reaction time/decision speed (Gt). Next in breadth of coverage is the DAS (Table 9.2), which includes measures of narrow abilities under all but the broad Ga and Gt factors (the complete battery also includes Grw measures).

The remaining four test batteries all provide coverage of narrow abilities under six broad Gf-Gc domains. All include tests that measure narrow abilities under Gc, Gsm, and Gv. All but the Wechsler batteries (Table 9.6) include some measures of narrow Gf abilities, and all but the KAIT (Table 9.4) have tests that measure some aspect of Gq. Similar to the DAS, the K-ABC (Table 9.3), KAIT, SB-IV (Table 9.5), and Wechsler batteries all do not include measures of Ga abilities. The KAIT is the only battery besides the DAS and WJ-R to include tests of Glr abilities. Finally, similar to the DAS and WJ-R, the Wechsler batteries are the only other battery to include tests of abilities under the broad Gs domain.

These results indicate that the DAS, KAIT, and WJ-R make the most unique contributions to psychoeducational assessment. The WJ-R is the only battery that includes tests of such narrow Ga abilities as awareness of and access to the sounds of language (i.e., phonological awareness). This is an important contribution given that "one of the most compelling and well established findings in the research on beginning reading is the important relation between phonological awareness and reading acquisitions" (Baker, Kameenui, Simmons, & Stahl, 1994, p. 379). The DAS, KAIT, and WJ-R

TABLE 9.2. Broad and Narrow Gf-Gc Factor Classification of the DAS Individual Cognitive and Achievement Tests

	Broad Gf-Gc Factors																
	Gf	Gq			Gc				Gsm		Gv		Glr	Gs		Grw	
Narrow Factor Name:	Ind	Quan Reas	Math Know	Math Ach	Lng Dev	Lex Know	Lst Abl	Gnrl Info	Mem Span	Vis Mem	Vis	Spt Rel	FrRe Mem	Prc Spd	Rate TsTk	Spl Abl	Rdg Dec
Narrow Factor Code:	I	RQ	KM	A3	LD	VL	LS	KO	MS	MV	VZ	SR	M6	P	R9	SG	RD
Pic. Similarities (gf)	x																
Matrices (Gf)	X																
Seq. & Quan. Reas. (Gf/Gq)	X	X															
Verbal Comprehension (gc)					x		x										
Naming Vocabulary (gc)					x	x		o									
Word Definitions (Gc)					X	X											
Similarities (Gc)					X	O		O									
Copying (gv)											o						
Recall of Designs (Gsm)										X							
Pattern Construction (Gv)											X	X					
Block Building (gv)											x	x					
Mat. Letter-Like Forms (gv)											x	x					
Recall of Digits (gsm)									x								
Recall of Objects (glr/gsm)										o			x				
Recognition of Pict. (gsm/gv)										x	o						
Speed of Info. Proc. (gs)														x	x		
Early Num. Concepts (gq)		x	x	o													
Basic Number Skills (gq)		o	x	x													
Spelling (grw)																x	
Word Reading (grw)																	x

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as reported by McGhee (1993) and McGrew (1994), or, cannot be so classified due to no appropriate joint factor-analytic studies. Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGhee (1993) and McGrew (1994). "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Lower case "x's", "o's" and Gf-Gc notation (e.g., gf for Picture Similarities) indicate classifications that are primarily logically based due to either limited or no appropriately designed research studies. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Joint confirmatory factor studies and logical content analysis indicate that the DAS does not contain indicators of the Ga and Gt factors.

TABLE 9.3. Broad and Narrow Gf-Gc Factor Classification of the K-ABC Individual Cognitive and Achievement Tests

	Broad Gf-Gc Factors																
	Gf	Gq			Gc				Gsm		Gv				Grw		
Narrow Factor Name:	Ind	Quan Reas	Math Know	Math Ach	Lng Dev	Lex Know	Gnrl Info	Info Cltr	Mem Span	Vis Mem	Vis	Spt Rel	Cls Spd	SerP Int	Rdg Dec	Rdg Cmp	Vrbl Cmp
Narrow Factor Code:	I	RQ	KM	A3	LD	VL	KO	K2	MS	MV	VZ	SR	CS	PI	RD	RC	V
Hand Movements (Gsm/Gq)		O							X	X							
Number Recall (Gsm)									X								
Word Order (Gsm)									X								
Magic Window (gv)											o		o	x			
Face Recogn. (gsm/gv)										x	x						
Gestalt Closure (Gv)													X				
Triangles (Gv)											X	X					
Matrix Anal. (Gv/Gf)											X						
Spatial Memory (Gv/gsm)									x	x		O					
Photo Series (Gv/Gf)	X										X						
Expressive Voc. (Gc)					X	X	O										
Faces and Places (Gc)							X	X									
Riddles (Gc)					X	X	O										
Arithmetic (Gq)		X	O	X													
Reading/Decoding (grw)															x		
Reading/Understanding (grw)																x	x

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined by Woodcock (1990). Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGrew (1994) and Woodcock (1990). "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Lower case "x's", "o's" and Gf-Gc notation (e.g., grw for reading tests) indicate classifications that are primarily logically based due to either limited or no appropriately designed research studies. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Joint confirmatory factor studies and logical content analysis indicate that the K-ABC does not contain indicators of the Ga, Glr, Gs, and Gt factors.

TABLE 9.4. Broad and Narrow Gf-Gc Factor Classification of the KAIT Individual Tests

	Broad Gf-Gc Factors													
	Gf		Gc					Gsm		Glr		Grw		
Narrow Factor Name:	Seq Reas	Quan Ind	Lng Know	Lex Dev	Lst Know	Gnrl Abl	Info Cltr	Mem Span	Vis Mem	Assc Mem	Mng Mem	Rdg Dec	Spl Abl	Vrbl Cmp
Narrow Factor Code:	RG	I	LD	VL	LS	KO	K2	MS	MV	MA	MM	RD	SG	V
Definitions (Gc/Grw)			X	X								O	X	
Auditory Compr. (Gc/Gsm)			X		X			X						
Double Meanings (Gc/Grw)				X										X
Famous Faces (Gc)						X	X							
Del. Rec. -AdCm. (Glr/Gc)			O								X			
Rebus Learning (Glr)										X				
Logical Steps (Gf)	X	O												
Mystery Codes (Gf)		X												
Mem. Blk. Des. (Gsm)									X					
Del. Rec. -Relrn. (Glr)										X				

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined by Flanagan and McGrew (1995). Gf-Gc notations in parentheses correspond to primary factor classifications as reported by Flanagan and McGrew (1995). "X's" indicate most "probable" narrow factor classifications; "O's" indicate possible narrow factor classifications. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Joint confirmatory factor studies and logical content analysis indicate that the KAIT does not contain indicators of the Gq, Gv, Ga, Gs, and Gt factors.

TABLE 9.5. Broad and Narrow Gf-Gc Factor Classification of the SB:IV Individual Tests

	Broad Gf-Gc Factors									
	Gf	Gq		Gc			Gsm		Gv	
Narrow Factor Name:	Ind	Quan Reas	Math Know	Lng Dev	Lex Know	Gnrl Info	Mem Span	Vis Mem	Vis	Spt Rel
Narrow Factor Code:	I	RQ	KM	LD	VL	KO	MS	MV	VZ	SR
Vocabulary (Gc)				X	X					
Comprehension (Gc)				X		X				
Absurdities (Gc)				X		O				
Verbal Relations (Gc)				X	O	O				
Pattern Analysis (Gv)									O	X
Copying (Gv)									X	
Matrices (Gf)	X									
Paper Fold. & Cut. (Gv/Gq)		O							X	
Quantitative (Gq)		X	O							
Number Series (Gq)		X								
Equation Building (Gq)		X	O							
Bead Memory (Gsm/Gv)								X	O	
Mem. for Sent. (Gsm/Gc)				X			X			
Memory for Digits (Gsm)							X			
Memory for Objects (Gsm)								X		

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined by Woodcock (1990). Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGrew (1994) and Woodcock (1990). "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Joint confirmatory factor studies and logical content analysis indicate that the SB:IV does not contain indicators of the Ga, Glr, Gs, and Gt factors.

TABLE 9.6. Broad and Narrow Gf-Gc Factor Classification of the Wechsler Individual Tests

	Broad Gf-Gc Factors												
	Gq		Gc			Gsm	Gv					Gs	
Narrow Factor Name:	Quan Reas	Math Know	Lng Dev	Lex Know	Gnrl Info	Mem Span	Vis	Spt Rel	Cls Spd	Flex Cls	Spt Scan	Prc Spd	Rate TsTk
Narrow Factor Code:	RQ	KM	LD	VL	KO	MS	VZ	SR	CS	CF	SS	P	R9
Information (Gc)					X								
Similarities (Gc)			X	O	O								
Vocabulary (Gc)			X	X									
Comprehension (Gc)			X		X								
Pict. Completion (Gv/Gc)					O		O			O			
Pict. Arrangement (Gv/Gc)			O				O						
Block Design (Gv)							X	X					
Object Assembly (Gv)							X		X				
Mazes (Gv)											X		
Coding/Digit Symbol (Gs)												X	X
Symbol Search (gs)												x	x
Arithmetic (Gq)	X	O											
Digit Span (Gsm)						X							

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined by Woodcock (1990). Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGrew (1994) and Woodcock (1990). "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Lower case "x's", "o's" and Gf-Gc notation (e.g., gs for Symbol Search) indicate classifications that are primarily logically based due to either limited or no appropriately designed research studies. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Joint confirmatory factor studies and logical content analysis indicate that the Wechsler batteries do not contain indicators of the Gf, Ga, Glr, and Gt factors.

TABLE 9.7. Broad and Narrow Gf-Gc Factor Classification of the WJ-R Individual Cognitive Tests

	Broad Gf-Gc Factors																			
	Gf		Gq	Gc				Gsm		Gv				Ga				Glr	Gs	
Narrow Factor Name:	Seq Reas	Ind	Quan Reas	Lng Dev	Lex Know	Lst Abl	Gnrl Info	Mem Span	Vis Mem	Vis	Spt Rel	Cls Spd	Spt Scan	Phn Cod	SpSd Disc	Res AdDs	Mem SndP	Assc Mem	Prc Spd	Rate TsTk
Narrow Factor Code:	RG	I	QR	LD	VL	LS	KO	MS	MV	VZ	SR	CS	SS	PC	US	UR	UM	MA	P	R9
Analysis-Synthesis (Gf)	X		O																	
Concept Formation (Gf)		X	O																	
Verbal Analogies (Gf-Gc)		X		X	X															
Picture Vocabulary (Gc)				X	X		O													
Oral Vocabulary (Gc)				X	X															
List. Comprehension(Gc)				X		X														
Mem. for Sent. (Gsm/Gc)				X				X												
Memory for Words (Gsm)				O				X												
Numbers Reversed (Gsm/Gf)	X							X												
Visual Closure (Gv)												X								
Pict. Recogn. (Gsm/Gv)									X	O								O		
Spatial Relations (Gv/Gf)	X									X	X									
Incomplete Words (Ga)														X		O				
Sound Blending (Ga)														X						
Sound Patterns (Ga/Gf)	O														O		O			
Memory for Names (Glr)																		X		
Vis-Aud Learning (Glr)																		X		
Delayed Recall - MN (Glr)																		X		
Delayed Recall - VAL (Glr)																		X		
Visual Matching (Gs)																			X	X
Cross-Out (Gs)													O						X	X

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined Woodcock (1990). Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGrew (1994) and Woodcock (1990) and modified by new WJ-R analyses reported in this chapter and that reported by Flanagan and McGrew (1995). "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Tests of the Grw factor, and additional tests of the Gq, Gf, Gc, Ga, and Gs

TABLE 9.8. Broad and Narrow Gf-Gc Factor Classification of the WJ-R Individual Achievement Tests

	Broad Gf-Gc Factors																		
	Gf	Gq			Gc						Ga	Gs	Grw						
Narrow Factor Name:	Seq Reas	Quan Reas	Math Know	Math Ach	Lng Dev	Lex Know	Gnrl Info	Info Cult	Sci Info	Geo Ach	Phn Cod	Rate TsTk	Rdg Dec	Rdg Cmp	Vrbl Cmp	Clz Abl	Spl Abl	Wrt Abl	Eng UsKn
Narrow Factor Code:	RG	RQ	KM	A3	LD	VL	KO	K2	K1	A5	PC	R9	RD	RC	V	CZ	SG	WA	EU
Calculation (Gq)			O	X															
Applied Problems (Gq)	O	X		X	O														
Quant. Concepts (Gq)		O	X	X		O													
Science (Gc)						O	X		X										
Social Studies (Gc)						O	X			X									
Humanities (Gc)						O	X	X											
Letter-Word Iden. (Grw)													X						
Passage Comp. (Grw)					O									X	X	X			
Word Attack (Grw)											X		X						
Rdg. Vocabulary (Grw/Gc)						X							X		X				
Writing Samples (Grw)															O	O		X	
Writing Fluency (Grw/Gs)												X						X	
Punctuation (Grw)															O				X
Spelling (Grw)															O		X		O
Usage (Grw)															O				X
Handwriting (Grw)																		X	

Note. Tests in bold are "strong" indicators of their respective Gf-Gc factors; tests not in bold are either "moderate" measures of a Gf-Gc factor or "mixed" measures of more than one Gf-Gc factor as empirically defined by Woodcock (1990) and modified by new WJ-R analyses reported in this chapter. Gf-Gc notations in parentheses correspond to primary factor classifications as reported by McGrew (1994) and Woodcock (1990) and modified by new WJ-R analyses reported in this chapter. "X's" indicate most "probable" narrow factor classifications; "O's" indicate "possible" narrow factor classifications. Detailed definitions of the factor names, with their respective factor codes, are presented in Table 9.1. Tests of the other Gf-Gc factors from the cognitive section of the complete WJ-R battery are reported in Table 9.7.

all provide for measurement of some narrow Glr abilities which are not covered by traditional intelligence tests such as the Wechslers and SB-IV.

Breadth of Coverage of the Gf-Gc Framework

A frequency count of measures of the different narrow ability factors is presented in Table 9.9.

A review of Table 9.9 indicates that narrow abilities under Gc (67) and Gv (36) are the most frequently represented abilities in our current collection of individual intelligence batteries. There is no shortage of tests of narrow abilities that can be considered indicators of the broad Gc and Gv abilities. The Gq (28) and Grw (27) abilities are next, but these results cannot accurately be compared with the other broad Gf-Gc abilities because they include measures from three achievement batteries that accompany only three of the intelligence batteries (i.e., DAS, K-ABC, and WJ-R). Narrow abilities under the Gsm (22) domain are also represented by a good number of tests.

Gs (11), Glr (9), and especially Ga (6) are the broad Gf-Gc abilities that have the smallest number of tests of narrow abilities under each broad domain. Given the significant relationship between some of the narrow abilities within these broad Gf-Gc domains and school achievement (McGrew, 1993, 1994; McGrew & Hessler, 1995; McGrew & Knopik, 1993; Baker et al., 1994), this ability "undercoverage" will most likely change in the future with the development of new, and revisions to old, tests.

The finding that Gf (17) abilities are fourth from the bottom in Table 9.9 is important. Fluid intelligence or reasoning is often considered the essence of intelligence by both scholars and laypeople. One would think that Gf abilities would be prominently featured in all intelligence batteries. This finding appears due to the fact that tests that have been historically considered to be good measures of Gf abilities (e.g., Wechsler Block Design and Similarities) are now found to primarily be measures of other constructs. In particular, many nonverbal visual-spatial tasks (e.g., Wechsler Block Design and Object Assembly) are measures of narrow abilities in the broad domain of Gv and not Gf (McGrew & Flanagan, 1996).

A final word of caution: Not all the classifications presented in Tables 9.2 to 9.8 are made with equal confidence. For most of the individual tests the empirical factor-analytic data were clear and the expert classifications consistent. I found the test classifications the easiest for the DAS, KAIT, SB-IV, and WJ-R. This is not unexpected given that each of these test batteries has been either directly or indirectly, or completely or partially, influenced by the Gf-Gc-related factor-analytic research literature. Therefore, with a few exceptions the reader can place more confidence in the Gf-Gc classifications of the DAS, KAIT, SB-IV, and WJ-R batteries.

I found the K-ABC battery, and a number of the simultaneous processing tests in particular (i.e., Magic Window, Photo Series, and Spatial Memory), to be some of the most difficult tests to classify. The classifications for the DAS and SB-IV Copying tests should also be viewed cautiously. Although they have Gv-related classifications, performance on these tests is probably related to motor abilities not included in the Gf-Gc framework. The WJ-R Sound Patterns test has always been a "maverick" test in available joint factor-analytic studies. There is still a significant portion of the Sound Patterns test variance that is not yet understood from the Gf-Gc perspective. One hypothesis is that performance on the Sound Patterns test may be influenced by attention and concentration abilities (McGrew et al., 1991).

Finally, the classification of the Wechsler Picture Arrangement test was difficult. In joint factor-analytic studies, this test showed only relatively low to moderate factor loadings (i.e., from approximately .10 to .35) on Gv- and Gc-related factors. Although expert classifications often suggested some narrow abilities under the Gf domain, the empirical studies reviewed never supported this logical claim. The Picture Arrangement test may be influenced by other abilities outside the domain of Gf-Gc theory. Possibly some aspects of practical or social intelligence from a larger model of

TABLE 9.9. Number of Tests from Reviewed Batteries That Measure Gf-Gc Factors

Gf-Gc broad/narrow factors	Code	Number
Crystallized Intelligence/Knowledge (Gc)		(67)
Language Development	LD	26
Lexical Knowledge	VL	19
General (verbal) Information	KO	17
Information about Culture	K2	3
Listening Ability	LS	3
General Science Information	K1	1
Geography Achievement	A5	1
Visual Intelligence/Processing (Gv)		(36)
Visualization	VZ	20
Spatial Relations	SR	8
Closure Speed	CS	4
Spatial Scanning	SS	2
Flexibility of Closure	CF	1
Serial Perceptual Integration	PI	1
Quantitative Reasoning/Knowledge (Gq)		(28)
Quantitative Reasoning	RQ	14
Mathematical Knowledge	KM	8
Mathematical Achievement	A3	6
Reading/Writing (Grw)		(27)
Verbal (printed) Language Compr.	V	
Reading Decoding	RD	6
Spelling Ability	SG	3
Writing Ability	WA	3
English Usage Knowledge	EU	3
Reading Comprehension	RC	2
Cloze Ability	CZ	2
Short-Term Memory (Gsm)		(22)
Memory Span	MS	12
Visual Memory	MV	10
Fluid Intelligence/Reasoning (Gf)		(17)
Induction	I	10
General Sequential Reasoning	RG	7
Cognitive Processing Speed (Gs)		(11)
Rate-of-Test-Taking	R9	6
Perceptual Speed	P	5
Long-Term Associative Storage & Retrieval (Glr)		(9)
Associative Memory	MA	7
Meaningful Memory	MM	1
Free Recall Memory	M6	1
Auditory Intelligence/Processing (Ga)		(6)
Phonetic Coding	PC	3
Speech Sound Discrimination	US	1
Resistance to Aud. Stimulus Distortion	UR	1
Memory for Sound Patterns	UM	1

personal competence (see Greenspan & Driscoll, Chapter 8, this volume) may account for the unexplained variance in Picture Arrangement.

Unique Test Contributions at the Gf-Gc Narrow Ability Level

Because there is considerable overlap within and across test batteries in the assessment of some Gf-Gc abilities (e.g., 19, 20, and 26 tests classified as Gc measures of Lexical Knowledge, General or Cultural Information, and Language Development, respectively, see Table 9.9), it is more informative to look at which tests make unique contributions. From a review of Table 9.9, the following unique contributions are noted.

In the domain of Gc, the DAS Verbal Comprehension, KAIT Auditory Comprehension, and WJ-R Listening Comprehension tests are the only measures of Listening Ability (LA) in the six batteries reviewed. The Gv domain is adequately represented by measures of Visualization (VZ) and Spatial Relations (SR). Unique Gv contributions are made by the K-ABC Magic Window and Gestalt Closure, Wechsler Object Assembly, and WJ-R Visual Closure tests in the area of Closure Speed (CS). The Wechsler Mazes and WJ-R Cross-Out tests may assist in the measurement of Spatial Scanning (SS), whereas the Wechsler Picture Completion test may measure some aspects of Flexibility of Closure (CF). Finally, the K-ABC Magic Window test may be a unique measure of Serial Perceptual Integration (PI) abilities.

There appears to be no unique test contributions in the broad Gsm, Gf, and Gs ability domains. A review of Table 9.9 finds a relatively equal representation of Memory Span (MS) and Visual Memory (MV) abilities in the Gsm domain, Induction (I) and General Sequential (deductive) Reasoning (RG) abilities for Gf, and Rate-of-Test-Taking (R9) and Perceptual Speed (P) abilities for Gs.

As noted previously, all the tests that measure narrow abilities within the broad Glr and Ga domains make unique contributions to intellectual assessment. The KAIT Rebus Learning and Delayed Recall–Rebus Learning tests and the four WJ-R Long-Term Retrieval tests all appear to provide coverage of the Glr Associative Memory (MA) ability. Even more unique contributions within the Glr domain are made in the assessment of Meaningful Memory (MM) and Free Recall Memory (M6) by the KAIT Delayed Recall–Auditory Comprehension and DAS Recall of Objects tests, respectively.

Finally, the WJ-R Incomplete Words and Sound Blending tests make unique contributions in the domain of Ga by their assessment of Phonetic Coding (PC) abilities. In addition, the Incomplete Words test may provide unique coverage of Resistance to Auditory Distortion (UR) abilities. The Sound Patterns test also appears to make a contribution by measuring Speech Sound Discrimination (US) and Memory for Sound Patterns (UM) abilities.

Gf-Gc Abilities in Tests of Achievement

The distinction between intelligence and achievement distinction is largely an artificial dichotomy used in educational settings. With this caveat in mind, it is informative to examine the Gf-Gc analysis of tests traditionally considered to measure "achievement."

For example, the WJ-R Passage Comprehension reading test has its primary narrow ability classifications under the Grw factor. A review of Table 9.8 indicates that it also has a "possible" Language Development classification under Gc. The WJ-R Applied Problems test, although primarily classified under Gq, also has General Sequential Reasoning (Gf) and Language Development (Gc) classifications. The Phonetic Coding (Ga) classification of the WJ-R Word Attack reflects another "cognitive" influence on an achievement task. These results suggest that both researchers and clinicians need to be sensitive to the fact that achievement tests may be more factorially complex than their test names suggest. Competent interpretation of achievement tests requires the same attention to multiple Gf-Gc influences as that suggested for the more traditionally labeled tests of intelligence.

IMPLICATIONS FOR RESEARCH AND PRACTICE

The implications of the information presented in this chapter are numerous and only limited by how long one studies and digests the results in the various tables. At a minimum, this form of analysis has six major implications.

First, the use of consistent ability terminology can only improve the interpretation of intelligence tests. The clinical literature is replete (including my own book on the WJ-R; McGrew, 1994) with the use of test interpretation terms such as "fund of information," "verbal concept formation," "visual perception of meaningful stimuli," and the "ability to distinguish essential from nonessential details," to list but a few. The origin of most of these terms would be difficult to trace, with most being passed down through the clinical literature, often without empirical support. I believe that test developers, scholars, and clinicians should anchor the dialogue on what different individual tests measure in terminology that is empirically grounded. The consistent use of the first-order narrow ability factor definitions (Table 9.1) might go far in helping us all better understand what we are measuring, facilitate better communication between and among professionals and scholars, and increase our ability to compare individual tests across and within intelligence batteries.

Second, it is clear that a *cross-battery* approach to assessment (McGrew & Flanagan, 1995; Flanagan & McGrew, Chapter 17, this volume; Woodcock, in press) is necessary to competently assess the major Gf-Gc human abilities. For example, clinicians who are strong advocates of the Wechsler batteries need to consult Table 9.6 to identify those Gf-Gc abilities that are not assessed by the Wechsler batteries. Strong measures of Gf abilities (e.g., SB-IV Matrices, KAIT Mystery Codes and Logical Steps, and WJ-R Concept Formation and Analysis-Synthesis), Ga abilities (e.g., WJ-R Auditory Processing tests), and Glr abilities (e.g., KAIT Rebus Learning and WJ-R Long-Term Retrieval tests) should be added to the Wechsler batteries to better "round out" a complete assessment (i.e., including tests that measure at least one narrow ability factor under each broad Gf-Gc domain). As another example, the WJ-R does not include "strong" measures of Gv abilities (Table 9.7). Thus, users of the WJ-R should seriously entertain the augmentation of their assessments with one or more strong measures of at least one narrow ability under the broad Gv domain (e.g., Wechsler Block Design or Object Assembly).

Not only is this cross-battery approach useful in performing more complete assessments, it can help when following up interpretive hypotheses (McGrew, 1994; McGrew & Flanagan, 1995; Flanagan & McGrew, Chapter 17, this volume). For example, a clinician may observe a relatively low score on the SB-IV Matrices test, a strong measure of Induction (I) abilities under Gf. However, because the SB-IV does not include other strong Gf measures (Table 9.5), the clinician could seek additional verification of this weakness by selecting a strong Inductive Gf measure from another battery (e.g., DAS Matrices, KAIT Mystery Codes, or WJ-R Concept Formation). Or, because the SB-IV Matrices test is primarily a measure of Induction, the clinician may want to augment it with a strong test of General Sequential (deductive) Reasoning (e.g., WJ-R Analysis–Synthesis) to more comprehensively sample the person's broad Gf abilities. By consulting the test classifications presented in Tables 9.2 to 9.8, clinicians should be able to improve their clinical interpretation of tests.

Third, the classification of individual tests by narrow abilities can help clinicians understand why a person may perform differently on two tests that have the same broad Gf-Gc label. I am frequently asked such questions as, "Why do I often get different scores on the WJ-R Analysis–Synthesis and Concept Formation tests if they are both measuring fluid intelligence [Gf]?" The analyses presented in this chapter indicate that the broad Gf-Gc abilities are second-order abilities that subsume narrower abilities that are strongly related but are still different in many respects. In the case of the two WJ-R tests, a review of Table 9.7 finds that although both tests are considered measures of Gf, the difference in test scores may be due to Analysis–Synthesis being more a measure of deductive (General Sequential Reasoning) reasoning whereas Concept Formation is more a measure of Inductive reasoning. The test summary tables should help clinicians understand why tests of narrow abilities in the same broad Gf-Gc ability often produce different scores.

Fourth, the availability of a comprehensive, empirically supported Gf-Gc model, together with theory-based data-analytic techniques such as confirmatory factor analysis (see Keith, Chapter 20, this volume), should help researchers and test developers design and conduct better studies. Theory-driven analyses with known narrow and/or broad Gf-Gc "marker" tests from across batteries should help researchers and test developers design better assessment batteries and increase our understanding of what existing assessment batteries measure. The studies of Flanagan and McGrew (1995), McGhee (1993), and Woodcock (1990) are illustrative of this approach to assessment research.

By focusing on the first-order narrow ability level, test developers can design test batteries that provide for more valid measurement of the broad Gf-Gc abilities by including measures of more than one narrow ability under a broad Gf-Gc ability. Also, it is now possible with appropriately designed studies to examine the advertising claims and clinical lore of what the individual tests in intelligence batteries measure (e.g., Wechsler Block Design is primarily a measure of narrow visual processing abilities, not fluid reasoning abilities) (McGrew & Flanagan, 1996). Maybe future versions of the Wechsler batteries will include good measures of Induction or General Sequential Reasoning (Gf) modeled after other good Gf tests (e.g., KAIT Mystery Codes and Logical Steps, DAS and SB-IV Matrices, and WJ-R Analysis–Synthesis and Concept Formation).

Fifth, the summary analyses across intelligence batteries highlight abilities that are well represented by existing tests (e.g., Language Development, Lexical Knowledge, and General Information areas in Gc) and abilities that are not assessed, or are assessed by a limited number of tests. These results suggest fruitful avenues for the development of new measures. Test developers need to consider developing new and innovative measures within the Ga and Glr domains. Examining the complete narrow ability definition list (Table 9.1) for abilities not measured by any intelligence battery (Table 9.9) suggests areas for future test development (e.g., Communication Ability under Gc, all the fluency abilities under Glr, and Sensitivity to Problems under Glr).

Finally, I have found the Gf-Gc framework and list of narrow ability definitions to be effective teaching tools. Students (or one's self, if pursuing self-study) can be required to classify the individual tests in an assessment battery according to the narrow ability definition list (Table 9.1). Such detailed task analysis of tests forces an individual to take a serious look at the task demands of individual tests. At the same time, the process increases an individual's understanding of the narrow and broad abilities within the Gf-Gc framework.

SUMMARY

These are exciting times for those involved in research, development, and the use of intelligence test batteries. Within the last decade the predominant verbal–nonverbal assessment model (i.e., the Wechsler batteries), a model that has remained largely unchanged since the 1939 publication of the Wechsler–Bellevue, has been challenged by instruments based on more contemporary theories and data. Although arguments may exist between different theoretical camps (e.g., the Luria–Das processing theories, Gardner's multiple intelligences theory, factor analytically based structural theories, and the more complete or modern Gf-Gc theories that include 9 to 10 abilities versus the older Gf-Gc dichotomy), there is little doubt that the seminal work of Carroll cannot be ignored, regardless of one's theoretical orientation. Only the most rigid of individuals would suggest that the emerging picture of the structure of human abilities derived from a systematic synthesis of 60 to 70 years of factor-analytic research should be ignored. Ignoring the seminal work of Carroll, which provides strong support for the Horn–Cattell Gf-Gc theory, would be akin to burying one's head in the sand.

Although my analyses highlight assessment batteries that may provide for the most comprehensive assessment of the narrow and/or broad Gf-Gc abilities, my goal is not to argue for reliance on a particular battery. Researchers and clinicians should use the information summarized in this chapter and the extension of this work by McGrew and Flanagan (1995), and Flanagan and McGrew (Chapter 17, this volume) to improve their research and clinical practice by cutting across batteries to conduct more thorough assessments. In particular, I want clinicians to become more true scientist–practitioners by using the best available empirical knowledge to inform their clinical assessment practice.

My classification of the individual tests in the major intelligence batteries is only an initial attempt in light of the emerging Gf-Gc models articulated by Carroll and Horn and are at best informed and reasoned hypotheses that need to be tested. The final Gf-Gc framework that I used to organize the test classifications was based partially on the Carroll versus Horn model analyses that I described in the Appendix, analyses that are based on limited sets of data and indicators. However, any errors in the placement of narrow abilities under the broad Gf-Gc abilities do not affect the narrow ability test classifications reported in this chapter. Future research and scholarly discussions will find that some of my classifications (most of them, I hope) are accurate, whereas others need modification. I fully expect this to happen. What is important is that this initial attempt begins to engage scholars and clinicians in a structured dialogue within a common framework and set of terms. If this is the end result of this chapter, I will be pleased. The monumental works of Carroll and Horn must begin to inform psychoeducational assessment practice, a professional activity that is too often influenced by arm-chair speculation and the inertia of tradition.

NOTES

1. A document with more detailed first-order narrow ability definitions can be obtained by contacting the author.
2. The following individuals provided their time and expertise in this activity: Vinny Alfonso, Ted Andrews, Colin Elliott, Dawn Flanagan, Patti Harrison, Gary Hessler, Rick Ittenbach, Alan Kaufman, Tim Keith, and Ron McGhee.

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APPENDIX

To evaluate the differences between the Carroll and Horn models, I used 37 measures from the WJ-R in the kindergarten to adult (n = 1291) norm sample described by McGrew et al. (1991). Using confirmatory factor methods, I compared four different Gf-Gc models. The initial specification of the composition of the factors (i.e., what WJ-R measures loaded on the different factors) was based on a review of the factor loadings reported by McGrew et al. (1991), Woodcock (1990), and John Carroll (presented later in this appendix).

The factor labels used in this Appendix are consistent with the stratum level I narrow factor definitions provided by Carroll (1993). These factor labels differ from the Gf-Gc factor labels commonly used to describe the WJ-R factors (Gf, Gc, Glr, Gsm, etc.) as the interpretation of prior WJ-R confirmatory studies tended to confound Carroll's stratum level II broad Gf-Gc factors with stratum level I narrow factors (Flanagan & McGrew, 1995). I evaluated the breadth of each factor specified in these analyses against the definitions provided by Carroll and used either stratum level II broad Gf-Gc factor notations (e.g., Ga) or stratum level I factor labels followed by their respective stratum level II labels (e.g., Phonetic Coding or PC-Ga), depending on the diversity of tests represented by each factor. For example, five factors in these analyses (i.e., Gv, Gc, Gf, Gq, and Grw) retained the broad Gf-Gc factor labels because task analysis of the diversity of indicators defining these factors suggested that these are broader factors more consistent with Carroll's stratum level II Gf-Gc factors. Some factors that have been labeled as stratum level II Gf-Gc factors in previous studies (e.g., the WJ-R Sound Blending and Incomplete Words based factor label of Ga) have been given a stratum level I label in these analyses because the indicators that define these factors are measures of only a stratum level I or narrow factor (e.g., PC). For a factor to retain a stratum level II broad Gf-Gc factor label, it must be broad; that is, composed of two or more different stratum level I narrow abilities tests. Thus, a limitation of these analyses is that four of the broad Gf-Gc factors (i.e., Glr, Gsm, Gs, and Ga) specified in these analyses were defined by only one stratum level I narrow factor.

Model 1 was specified to approximate, to the extent possible with the given breadth of variables, the major features of Carroll's model. Based on the Carroll and Horn model differences discussed earlier in this chapter, this model included six factors: combined Associative Memory (MA-Glr) and Memory Span (MS-Gsm); combined Gc and Grw; combined Gf and Gq; separate Gv, Perceptual Speed (PS-Gs), and Phonetic Coding (PC-Ga) factors (Incomplete Words and Sound Blending had dual loadings on the PC-Ga and Gc+Grw factor). This was one of the poorest fitting models (*rmr* = .05; *GFI* = .77; *AGFI* = .74). The Incomplete Words and Sound Blending loadings on the Gc+Grw factor were nonsignificant, and the linear structural equation modeling (LISREL) modification indices suggested the need for separate Memory Span (MS-Gsm) and Associate Memory (MA-Glr) factors.

Models 2 and 3 used the results from Model 1 and did not have the phonetic coding tests (i.e.,

TABLE 9.10. John Carroll's Hierarchical Exploratory Factor Analysis Solution (Principal Factoring with Hierarchical Orthogonalization of Factors with Schmid–Leiman Technique) of the Complete WJ-R Battery in Kindergarten to Adult Sample (n = 1,291)

	First-order factors										Second-order factors		
	1A	1B	1C	1D	1E	1F	1G	1H	1I	1J	2A	2B	h2[a]
1A: Auditory Processing											.74	—	.56
Sound Blending	.39	—	—	—	—	—	—	—	—	—	.45	—	.45
Incomplete Words	.37	—	—	—	—	—	—	—	—	—	.40	—	.32
Sound Patterns	.16	—	—	—	—	—	—	—	—	—	.33	—	.24
1B: Lexical Knowledge and Information											.66	**.45**	.63
Social Studies	—	.55	—	—	—	—	—	—	—	—	.57	**.34**	.77
Humanities	—	.47	—	—	—	—	—	—	—	—	.56	**.35**	.71
Science	—	.47	—	—	—	—	—	—	—	—	.59	—	.66
Oral Vocabulary	—	.45	—	—	—	—	—	—	—	—	.64	**.35**	.77
Picture Vocabulary	—	.42	—	—	—	—	—	—	—	—	.62	—	.63
Listening Comprehension	—	.41	—	—	—	—	—	—	—	—	.59	—	.60
Quantitative Concepts	—	.39	—	—	—	—	—	—	—	—	.41	**.56**	.72
Reading Vocabulary	—	.36	—	—	—	—	—	—	—	—	.57	**.44**	.75
Punctuation & Capitalization	—	.30	—	—	—	—	—	—	—	—	.32	**.59**	.63
Verbal Analogies	—	.28	—	—	—	—	—	—	—	—	.55	**.41**	.62
1C: Inductive Reasoning											.63	—	.40
Concept Formation	—	—	.35	—	—	—	**.31**	—	—	—	.46	**.33**	.55
1D: Visual Processing											.57	—	.35
Visual Closure	—	—	—	.33	—	—	—	—	—	—	.29	—	.23
Picture Recognition	—	—	—	.32	—	—	—	—	—	—	.32	—	.27
1E: Associative Memory											.51	—	.31
Delayed Recall/Memory For Names	—	—	—	—	.70	—	—	—	—	—	.43	—	.72
Memory for Names	—	—	—	—	.68	—	—	—	—	—	.44	—	.71
Visual-Auditory Learning	—	—	—	—	.35	—	—	—	—	—	.45	**.30**	.48
Delayed Recall/Vis.-Aud. Learning	—	—	—	—	.30	—	—	—	—	—	.35	—	.37
1F: Writing & Usage											—	.70	.52
Handwriting	—	—	—	—	—	.38	—	—	—	—	—	.32	.29
Writing Samples	—	—	—	—	—	.25	—	—	—	—	.38	.25	.60
Usage	—	—	—	—	—	.24	—	—	—	—	.37	.24	.61
1G: Quantitative Reasoning											—	.65	.48
Applied Problems	—	**.30**	—	—	—	—	.38	—	—	—	**.43**	.55	.72
Spatial Relations	—	—	—	**.33**	—	—	.36	—	—	—	**.38**	.31	.51
Calculation	—	—	—	—	—	—	.35	—	—	—	—	.63	.68
Analysis-Synthesis	—	—	—	—	—	—	.34	—	—	—	**.40**	.33	.44
1H: Perceptual Speed											—	.63	.44
Visual Matching	—	—	—	—	—	—	—	.61	—	—	—	.57	.74
Cross Out	—	—	—	—	—	—	—	.49	—	—	—	.45	.55
Writing Fluency	—	—	—	—	—	—	—	.23	—	—	—	.52	.49
1I: Orthography & Spelling											—	.57	.37
Word Attack	—	—	—	—	—	—	—	—	.52	—	**.37**	.46	.66
Letter-Word Identification	—	—	—	—	—	—	—	—	.47	—	**.46**	.52	.75
Spelling	—	—	—	—	—	—	—	—	.30	—	**.33**	.64	.72
Passage Comprehension	—	—	—	—	—	—	—	—	.29	—	**.48**	.45	.63
1J: Memory Span											—	.34	.13
Memory for Words	—	—	—	—	—	—	—	—	—	.64	**.30**	.30	.62
Memory for Sentences	—	—	—	—	—	—	—	—	—	.49	**.46**	.31	.64
Numbers Reversed	—	—	—	—	—	—	—	—	—	.24	**.32**	.43	.42
Sums of Squares	.42	2.20	.46	.56	1.21	.47	.88	.71	.99	.74	6.73	5.90	

Note. To save on space, loadings for the tests on the first- and second-order factors are listed in the respective columns. Loadings for the first-order factors on the second-order factors are listed in the respective columns. Nonsalient factor loadings are omitted from the table. Factor loadings in bold were not salient for a given factor but were greater than .295 in absolute magnitude. Loadings in the oblique reference-vector matrices, rather than the loadings in the pattern matrices, were used to determine salient loadings. Sums of squares (SMSQ) for first-order factors on second-order factors are 2.16 (2A) and 2.03 (2B); sum of communalities for first-order factors is 4.19. Sum of communalities for individual tests is 21.27. Second-order factors are labeled General Intelligence (2A) and Crystallized Intelligence (2B). This previously unpublished analysis was completed by John Carroll and is included here with his permission.

[a]h2 = communality estimate.

TABLE 9.11. Final Confirmatory Factor Analysis Solution of 37 Measures from the Complete WJ-R Battery in Kindergarten to Adult Sample (n = 1,291)

	Gf-Gc factor loadings								
	MA-	MS-	PS-	PC					
Tests	Glr	Gsm	Gs	Ga	Gv	Gc	Gf	Gq	Grw
Mem. for Names	.67	—	—	—	—	—	—	—	—
Vis.-Aud. Lrng.	.80	—	—	—	—	—	—	—	—
Delayed Recall—MN	.59	—	—	—	—	—	—	—	—
Delayed Recall—VAL	.51	—	—	—	**.14**	—	—	—	—
Memory for Sentences	—	.51	—	—	—	.50	—	—	—
Memory for Words	—	.71	—	—	—	**.24**	—	—	—
Numbers Reversed	—	.33	—	—	—	—	.49	—	—
Visual Matching	—	—	.86	—	—	—	—	—	—
Cross Out	—	—	.64	—	.25	—	—	—	—
Incomplete Words	—	—	—	.50	—	—	—	—	—
Sound Blending	—	—	—	.73	—	—	—	—	—
Sound Patterns	—	—	—	.26	—	—	.29	—	—
Picture Vocabulary	—	—	—	—	—	.76	—	—	—
Oral Vocabulary	—	—	—	—	—	.69	—	—	**.23**
Listening Compr.	—	—	—	—	—	.74	—	—	—
Verbal Analogies	—	—	—	—	—	.41	.45	—	—
Science	—	—	—	—	—	.80	—	—	—
Social Studies	—	—	—	—	—	.84	—	—	—
Humanities	—	—	—	—	—	.78	—	—	—
Analysis-Synthesis	—	—	—	—	—	—	.64	—	—
Concept Formation	—	—	—	—	—	—	.67	—	—
Calculation	—	—	—	—	—	—	—	.84	—
Applied Problems	—	—	—	—	—	.21	**.18**	.54	—
Quant. Concepts	—	—	—	—	—	.33	—	.61	—
Letter-Word Iden.	—	—	—	—	—	—	—	—	**.85**
Passage Compr.	—	—	—	—	—	**.23**	—	—	**.60**
Word Attack	—	—	—	.22	—	—	—	—	**.58**
Reading Vocabulary	—	—	—	—	—	**.44**	—	—	**.48**
Writing Samples	—	—	—	—	—	—	—	—	**.74**
Writing Fluency	—	—	.31	—	—	—	—	—	**.47**
Punct. & Cap.	—	—	—	—	—	—	—	—	**.76**
Spelling	—	—	—	—	—	—	—	—	**.84**
Usage	—	—	—	—	—	—	—	—	**.76**
Handwriting	—	—	—	—	—	—	—	—	**.26**

Note. Factor loadings in bold indicate significant parameters not previously reported by McGrew et al. (1990) or Woodcock (1990). Residual parameters and latent factor correlations not reported in table.

Incomplete Words and Sound Blending) loading on both Phonetic Coding (PC-Ga) and Gc. Both models also maintained separate Associative Memory (MA-Glr) and Memory Span (MS-Gsm) factors. Model 3 differed from Model 2 in the separation of the Grw and Gc factors. Both models maintained the combined Gf+Gq factor. Model 3 (*rmr* = .04; *GFI* = .90; *AGFI* = .88) was a better-fitting model than Model 2 (*rmr* = .05; *GFI* = .79; *AGFI* = .75). This comparison indicated the need to maintain separate Grw and Gc factors.

Model 4 was identical to Model 3, except that Model 4 included separate Gq and Gf factors. The fit of Model 4 was almost identical (*rmr* = .04; *GFI* = .91; *AGFI* = .89) to that for Model 3, indicating that both models were equally plausible. To try to resolve the issue whether Gf and Gq should be separate factors, I tested the independence of the two factors by running a model where the Gf/Gq latent factor correlation was fixed at 1.0. Compared to Model 3, where the Gf/Gq correlation was free to vary (r = .84), the chi-square difference of 126.58 (df = 1) was significant ($p < .05$), a finding in favor of separate factors.

Although the formal test indicated that Gf and Gq were separate factors, I was still uncomfortable with their high latent factor correlation of .84. Thus, I looked for other non–factor-analytic validity information regarding the two factors. Inspection of the growth curves for the Gf and Gq WJ-R clusters in the WJ-R norm data (see McGrew et al., 1991) reveals that these two abilities have markedly different patterns of growth and decline over the lifespan. This finding, together with the confirmatory factor results, indicate that Gf and Gq, as operationally defined by the WJ-R battery, are separate factors. Altogether, the results of these WJ-R analyses resulted in my conclusion that the best model to use in the classification of tests would be one that includes separate Gf, Gq, Gc, Grw, Glr, Gsm, Ga, Gv, and Gs factors. To help with the classification of the WJ-R battery tests, I then examined the LISREL modification indices from the final model (Model 4), and went through a number of iterations of adding suggested parameters to the factors in the model. The final results, with significant parameters not previously reported by McGrew et al. (1991) or Woodcock (1990) clearly marked, are presented in Table 9.11. Carroll's previously unpublished analyses, which he graciously has allowed me to report in this appendix, are based on the same factoring procedures he used throughout his massive review of the extant factor analyses research literature (Carroll, 1993). Carroll's results, which used the same 37 WJ-R measures, are presented in Table 9.10.

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Edited by

DAWN P. FLANAGAN
JUDY L. GENSHAFT
PATTI L. HARRISON

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