THE CHC CROSS-BATTERY ASSESSMENT APPROACH

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The Cattell-Horn-Carroll (CHC) Cross-Battery Assessment approach (hereafter referred to as the XBA approach) was introduced by Flanagan and her colleagues in the late 1990s (Flanagan & McGrew, 1997; Flanagan, McGrew, & Ortiz, 2000; Flanagan & Ortiz, 2001; McGrew & Flanagan, 1998). The XBA approach provides practitioners with the means to make systematic, valid, and up-to-date interpretations of intelligence batteries and to augment them with other tests in a way that is consistent with the empirically supported CHC theory of cognitive abilities. Moving beyond the boundaries of a single intelligence *test kit* by adopting the psychometrically and theoretically defensible XBA principles and procedures represents a significantly improved method of measuring cognitive abilities (Carroll, 1998; Decker, 2008; Kaufman, 2000).

According to Carroll (1997), the CHC taxonomy of human cognitive abilities "appears to prescribe that individuals should be assessed with respect to the *total range* of abilities the theory specifies" (p. 129). However, because Carroll recognized that "any such prescription would of course create enormous problems," he indicated that "[r]esearch is needed to spell out how the assessor can select what abilities need to be tested in particular cases" (p. 129). Flanagan and colleagues' XBA approach was developed specifically to "spell out" how practitioners can conduct assessments that approximate the total range of broad cognitive abilities more adequately than what is possible with most single intelligence batteries. In a review of the XBA approach, Carroll (1998) stated that it "can be used to develop the most appropriate information about an individual in a given testing situation" (p. xi). In Kaufman's (2000) review of XBA, he stated that the approach is based on sound assessment principles, adds theory to psychometrics, and improves the quality of the assessment and interpretation of cognitive abilities and processes.

The recent integration of neuropsychological theory in the XBA approach also “may improve school psychology assessment practice and facilitate the integration of neuropsychological methodology in school-based assessments...[because it] shift[s] assessment practice from IQ composites to neurodevelopmental functions” (Decker, 2008, p. 804).

Noteworthy is the fact that the “crossing” of batteries is not a new method of intellectual assessment. Neuropsychological assessment has long adopted the practice of crossing various standardized tests in an attempt to measure a broader range of brain functions than that offered by any single instrument (Lezak, 1976, 1995). Nevertheless, several problems with crossing batteries have plagued assessment-related fields for years. Many of these problems have been circumvented by Flanagan and colleagues’ XBA approach (see Table 1 for examples). But unlike the XBA approach, the various so-called “cross-battery” techniques applied within the field of neuropsychological assessment, for example, are not grounded in a systematic approach that is both psychometrically and theoretically defensible. Thus, as Wilson (1992) cogently pointed out, the field of neuropsychological assessment is in need of an approach that would guide practitioners through the selection of measures that would result in more specific and delineated patterns of function and dysfunction—an approach that provides more clinically useful information than one that is “wedded to the utilization of subscale scores and IQs” (p. 382). Indeed, all fields involved in the assessment of cognitive functioning have some need for an approach that would aid practitioners in their attempt to “touch all of the major cognitive areas, with emphasis on those most suspect on the basis of history, observation, and on-going test findings” (Wilson, 1992, p. 382). The XBA approach has revolutionized assessment practice by addressing these clinical issues. Moreover, with recent revisions, the XBA approach is now based on more psychometrically rigorous procedures and has a stronger cognitive and neuropsychological theoretical orientation than before. The definition of XBA assessment as well as the foundation, rationale for, and application of this approach are described briefly in the following paragraphs.

Need within Assessment-Related Fields[1]	**Need Addressed by the XBA Approach**
School Psychology, Clinical Psychology, and Neuropsychology have lagged in the development of conceptual models of the assessment of individuals. There is a need for the development of contemporary models.	The XBA approach provides a contemporary model for measurement and interpretation of cognitive and academic abilities and neuropsychological processes.
It is likely that there is a need for events external to a field of endeavor to give impetus to new developments and real advances in that field.	Carroll and Horn's *Fluid-Crystallized* theoretical models (and more recently Schneider and McGrew's [2012] CHC model) and research in cognitive psychology and neuropsychology provided the impetus for and continued refinements to the XBA approach and led to the development of better assessment instruments and interpretive procedures.
There is a need to utilize a conceptual framework to direct any approach to assessment. This would aid in both the selection of instruments and methods, and in the interpretation of test findings.	The XBA approach is based mainly on CHC theory, but also neuropsychological theory. Since the XBA approach links all the major intelligence and achievement batteries as well as selected neuropsychological instruments to CHC theory, in particular, both selection of tests and interpretation of test findings are made easier.
It is necessary that the conceptual framework or model underlying assessment incorporates various aspects of neuropsychological and cognitive ability function that can be described in terms of constructs which are recognized in the neuropsychological and cognitive psychology literature.	The XBA approach incorporates various aspects of neuropsychological and cognitive ability functions that are described in terms of constructs that are recognized in the literature. In fact, a consistent set of terms and definitions within the CHC literature (e.g., Schneider & McGrew, 2012) and the neuropsychology literature (e.g., Miller, in 2013) underlie the XBA approach.

[1] Information obtained, in part, from Wilson, B.C. (1992). The neuropsychological assessment of the preschool child: A branching model. In I. Rapin & S.I. Segalowitz (Eds.), *Handbook of neuropsychology: Child neuropsychology* (Vol. 6) (pp. 377-394).

Definition

The XBA approach is a time-efficient method of cognitive, academic, and neuropsychological assessment that is grounded in both CHC and neuropsychological theory and research (Flanagan, Alfonso, Ortiz, & Dynda, 2010; Flanagan, Ortiz, & Alfonso, 2013). It allows practitioners to reliably measure a wider range (or a more in-depth but selective range) of ability and processing constructs than that represented by any given stand alone assessment battery, in a reliable and valid way. The XBA approach is based on four foundational sources of information, that together provide the knowledge base necessary to organize theory-driven, comprehensive assessment of cognitive, academic, and neuropsychological constructs (Flanagan et al., 2013).

Foundations of the XBA Approach

The foundation of the XBA approach is built, in part, on contemporary CHC theory, the classification of broad and narrow CHC abilities that comprise *current* cognitive, achievement, and selected neuropsychological batteries (i.e., batteries published after 2000), and the relations between cognitive abilities, processes, and academic skills.

The first pillar of the XBA 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 Horn & Blankson, 2005; Schneider & McGrew, 2012). According to Daniel (1997), the strength of the multiple (CHC) cognitive abilities 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). Since its inception, the CHC theory remains to be the most validated and best description of human cognitive abilities (Ackerman & Lohman, 2006; Kaufman, 2009; Schneider & McGrew, 2012). Because the broad and narrow abilities that comprise CHC theory have been defined elsewhere in this book (see Flanagan & Dixon, this volume), these definitions will not be reiterated here.

The second pillar of the XBA approach is 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 (see Keith & Reynolds, 2010; Reynolds, Keith, Flanagan, & Alfonso, 2012), the task analyses of many cognitive and achievement test experts (as cited in Flanagan, Ortiz, Alfonso, & Mascolo, 2006), and current inter-rater reliability data on subtest classifications, Flanagan and colleagues classified all the subtests of the major cognitive and achievement batteries (and selected neuropsychological batteries) according to the particular CHC broad abilities they measured. The current XBA approach includes the classification of approximately 800 tests and subtests according to the broad CHC abilities they measured. These classifications of ability tests assist practitioners in identifying measures that assess various aspects of the broad abilities represented in CHC theory, such as Fluid Intelligence (*Gf*), Crystallized Intelligence (*Gc*), Short-Term Memory (*Gsm*), and Quantitative Knowledge (*Gq*). 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 that underlie 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 that are less “contaminated” by other constructs because they contain only measures that are relevant to the construct or ability of interest.

The third pillar of the XBA approach is the CHC narrow (stratum I) classifications of cognitive and academic ability tests. These classifications were originally reported in McGrew (1997). Subsequently, Flanagan and colleagues provided content validity evidence for the narrow ability classifications underlying the major intelligence and achievement batteries (Flanagan, Ortiz, Alfonso & Mascolo, 2002, 2006), and more recently tests of neuropsychological processes (e.g., Flanagan et al., 2010, 2013; Flanagan, Alfonso, Mascolo, & Hale, 2011). Use of narrow ability classifications were necessary to ensure that the CHC constructs that underlie assessments are well represented. That is, the narrow ability classifications of tests assist practitioners in combining qualitatively different narrow ability indicators (or tests) of a given broad ability into clusters so that appropriate inferences can be made from test performance.

The fourth pillar of the XBA approach is the relationships between cognitive abilities, processes, and academic skills. Understanding these dynamic relationships assists practitioners in formulating hypotheses about how and why a student’s cognitive strengths and weaknesses impact academic achievement. While a thorough discussion of these relations is beyond the scope of this entry, the interested reader is referred to Flanagan and colleagues (2006; 2007; 2013) and McGrew and Wendling (2010) for a detailed description of the relationships between cognitive abilities/processes and reading, math, and written language achievement. Taken together, the four pillars underlying the XBA approach provide the necessary foundation from which to organize assessments of cognitive and academic abilities and neuropsychological processes that are theoretically driven, comprehensive, and valid.

Rationale for the CHC Cross-Battery Approach

The XBA approach has significant implications for practice, research, and test development. A brief discussion of these implications follows.

Practice

The XBA approach provides "a much needed and updated bridge between current intellectual theory and research and practice" (Flanagan & McGrew, 1997, p. 322). The results of several joint factor analyses conducted over the past 20+ years demonstrated that none of our intelligence batteries contained measures that sufficiently approximated the full range of broad abilities that define the structure of intelligence specified in contemporary psychometric theory (e.g., Carroll, 1993; Horn, 1991; Keith, Kranzler, & Flanagan, 2001; McGrew, 1997; Phelps, McGrew, Knopik, & Ford, 2005; Woodcock, 1990). Indeed, the joint factor analyses conducted by Woodcock (1990) suggested that it may be necessary to "cross" batteries to measure a broader range of cognitive abilities than that provided by a single intelligence battery.

The findings of these joint factor analyses of intelligence batteries that were published prior to 2000 are presented in Table 2. As may be seen in this table, most batteries fall far short of measuring all seven of the broad cognitive abilities listed. Of the major intelligence batteries in use prior to 2000, most failed to measure three or more broad CHC abilities (viz., *Ga*, *Glr*, *Gf*, *Gs*) that were (and are) considered important in understanding and predicting school achievement. In fact, *Gf*, often considered to be the essence of intelligence, was either not measured or not measured adequately by most of the intelligence batteries included in Table 2.

The finding that the abilities not measured by the intelligence batteries listed in Table 2 are important in understanding children's learning difficulties provided the impetus for developing the XBA approach. In effect, the XBA approach was developed to systematically replace the x's in the "<2000" columns in Table 2 with tests from another battery. As such, this approach guides practitioners in the selection of tests, both core and supplemental, that together provides measurement of abilities that is considered sufficient in both breadth and depth for the purpose of addressing referral concerns.

Another benefit of the XBA approach is that it facilitates communication among professionals. Most scientific disciplines have a standard nomenclature (i.e., a common set of terms and definitions) that facilitates communication and guards against misinterpretation. For example, the standard nomenclature in chemistry is reflected in the *Periodic Table*; in biology, it is reflected in the classification of animals according to phyla; in psychology and psychiatry, it is reflected in the *Diagnostic and Statistical Manual of Mental Disorders*; and in medicine, it is reflected in the *International Classification of Diseases*. Underlying the XBA approach is a standard nomenclature or *Table of Human Cognitive Abilities* that includes classifications of hundreds of tests according to the broad and narrow CHC abilities they measure (see Flanagan et al., 2006, 2007, 2013). The XBA classification system has had a positive impact on communication among practitioners, has improved research on the relations between cognitive and academic abilities, and has resulted in substantial improvements in the measurement of cognitive constructs, as may be seen in the design and structure of current intelligence tests.

Finally, the XBA approach offers practitioners a psychometrically defensible means of identifying an individual's pattern of strengths and weaknesses. By focusing interpretation on cognitive ability clusters (i.e., via combinations of construct-relevant subtests) that contain either qualitatively different indicators of each CHC broad ability construct (to represent broad ability domains) or qualitatively similar indicators of narrow abilities (to represent narrow or specific ability domains), the identification of both normative and relative strengths and weaknesses is possible. Adhering closely to the XBA guiding principles and steps (described later) helps to ensure that the strengths and weaknesses identified via XBA are interpreted in a theoretically and psychometrically sound manner. In sum, the XBA approach addresses the longstanding need within the entire field of assessment, from learning disabilities to neuropsychological assessment, for methods that “provide a greater range of information about the ways individuals learn—the ways individuals receive, store, integrate, and express information” (Brackett & McPherson, 1996, p. 80).

Test Development

Although there was substantial evidence of at least eight or nine broad cognitive CHC abilities by the late 1980s, the tests of the time did not reflect this diversity in measurement. For example, Table 2 shows that the WPPSI-R, K-ABC, KAIT, WAIS-R, and CAS batteries only measured 2–3 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 DAS, SB:IV, and WISC-III did not provide sufficient coverage of abilities to narrow the gap between contemporary theory and practice, their comprehensive measurement of approximately four CHC abilities was nonetheless an improvement over the aforementioned batteries. Table 2 shows that only the 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 (see circles in the “<2000” columns for the WJ-R in Table 2; Alfonso, Flanagan, & Radwan, 2005; McGrew & Flanagan, 1998).

Test before 2000/ Test after 2000	*Gf*		*Gc*		*Gv*		*Gsm*		*Glr*		*Ga*	
	< 2000	2000>	< 2000	2000>	< 2000	2000>	< 2000	2000>	< 2000	2000>	< 2000	2000>
WISC-III/ WISC-IV	✗	✓	✓	✓	✓	✓	o	✓	✗	✗	✗	✗
WAIS-R/ WAIS-IV	✗	✓	✓	✓	✓	✓	o	✓	✗	✗	✗	✗
WPPSI-R/ WPPSI-III	✗	o	✓	✓	✓	✓	o	✗	✗	✗	✗	✗
KAIT	✓		✓		o		✗		✓		✗	
K-ABC/ KABC-II	o	✓	✗	✓	✓	✓	o	✓	✗	✓	✗	✗
CAS	✗		✗		✓		o		✗		✗	
DAS/ DAS-II	✓	✓	✓	✓	✓	✓	o	✓	o	✓	✗	o
WJ-R/ WJ-III	✓	✓	o	✓	✓	✓	o	✓	o	✓	o	✓
SB:FE/ SB5	✓	✓	✓	✓	✓	✓	o	✓	✗	✗	✗	✗

In general, Table 2 shows that *Gf*, *Gsm*, *Glr*, *Ga*, and *Gs* were not measured well by the majority of intelligence tests published prior to 2000. Therefore, it is clear that most test authors did not use contemporary psychometric theories of the structure of cognitive abilities 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 x's and o's in the "<2000" columns of Table 2 exemplify the "theory-practice gap" that existed in the field of intellectual assessment at that time (Alfonso et al., 2005).

In the past decade, CHC theory, has had a significant impact on the revision of old intelligence batteries. For example, a wider range of broad and narrow abilities is represented on current intelligence batteries than that represented on previous editions of these tests. Table 3 provides several salient examples of the impact that CHC theory and XBA classifications have had on intelligence-test development over the past two decades. Furthermore, 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., KABC). A review of Table 3 clearly illustrates the significant impact CHC theory and XBA classifications have had on recent test development.

Test (Year of Publication) **CHC and XBA Impact**	Revision (Year of Publication) **CHC and XBA Impact**
K-ABC (1983) **No obvious impact.**	**KABC-II (2004)** Provided a second global score that include fluid and crystallized abilities; Included several new subtests measuring reasoning; Interpretation of test performance may be based on CHC theory or Luria's theory; Provided assessment of five CHC broad abilities.
SB:FE (1986) **Used a three-level hierarchical model of the structure of cognitive abilities to guide construction of the test: the top level included 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)** Used CHC theory to guide test development; Increased the number of broad factors from 4 to 5; Included a Working Memory Factor based on research indicating its importance for academic success.
WPPSI-R (1989) **No obvious impact.**	**WPPSI-III (2002)** Incorporated measures of Processing Speed

	that yielded a Processing Speed Quotient based on recent research indicating the importance of processing speed for early academic success; Enhanced the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests.
WJ-R (1989) **Used modern *Gf-Gc* theory as the cognitive model for test development; Included two measures of each of eight broad abilities.**	**WJ III NU (2001, 2007)** Used CHC theory as a "blueprint" for test development; Included two or three qualitatively different narrow abilities for each broad ability; The combined cognitive and achievement batteries of the WJ III NU include 9 of the 10 broad abilities subsumed in CHC theory.
WISC-III (1991) **No obvious impact.**	**WISC-IV (2003)** Eliminated Verbal and Performance IQs; Replaced the Freedom from Distractibility Index with the Working Memory Index; Replaced the Perceptual Organization Index with the Perceptual Reasoning Index; Enhanced the measurement of fluid reasoning by adding Matrix Reasoning and Picture Concepts; Enhanced measurement of Processing Speed with the Cancellation subtest.
DAS (1990) **No obvious impact.**	**DAS-II (2007)** Measures 7 broad CHC broad abilities and also includes measures of certain narrow abilities not found on other major cognitive batteries (e.g., F6 or free recall memory).
WAIS-III (1997) **No obvious impact.**	**WAIS-IV (2008)** Eliminated Verbal and Performance IQs; Replaced the Perceptual Organization Index with the Perceptual Reasoning Index; Enhanced the measurement of fluid reasoning by adding the Figure Weights and Visual Puzzles subtests; Enhanced measurement of Processing Speed with the Cancellation subtest. Enhanced measurement of memory with the Working Memory Index.
WPPSI-III (2002) **Incorporated measures of Processing Speed that yielded a Processing Speed Quotient based on recent research indicating the importance of processing speed for early**	**WPPSI-IV (2012)** Eliminated Verbal and Performance IQs; Enhanced measures of working memory, processing speed, and inhibitory control.

academic success; Enhanced the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests.	

Of the seven intelligence batteries that were published since 2000, the test authors of four clearly used CHC theory and XBA classifications as a blueprint for test development (i.e., WJ III, SB5, KABC-II, and DAS-II). Only the authors of the Wechsler Scales (i.e., WPPSI-III/IV, WISC-IV, and WAIS-III) did not state explicitly that CHC theory was used as a guide for revision. Nevertheless, these authors acknowledged the research of Cattell, Horn, and Carroll in their most recent manuals (Wechsler, 2002, 2003, 2008). Presently, as Table 3 shows, nearly all intelligence batteries that are used with some regularity subscribe either explicitly or implicitly to CHC theory (Alfonso et al., 2005; Flanagan et al., 2006, 2011, 2012).

Convergence toward the incorporation of CHC theory is also seen clearly in Table 2. A comparison of tests published before and after 2000 demonstrates that many of the gaps in measurement of broad cognitive abilities (x's and o's in the "<2000" columns of Table 2) have been filled (✓'s in the ">2000" columns). First, the majority of tests published after 2000 now measure 4-5 broad cognitive abilities adequately (e.g. WISC-IV, WAIS-IV, KABC-II, and SB5) as compared to only 2-3 broad abilities measured prior to 2000. Second, Table 2 shows that the WJ III and DAS-II continue to include measures of seven broad cognitive abilities, although Gs is underrepresented on the WJ III and *Ga* is underrepresented on the DAS-II. Third, Tables 2 indicates that two broad abilities not measured by many intelligence batteries prior to 2000 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 intelligence batteries because of the accumulating research evidence regarding their importance in overall academic success (see

Flanagan, et al., 2006; and McGrew & Wendling, 2010, for a review). Finally, Table 2 reveals that intelligence batteries continue to fall short in their measurement of three CHC broad abilities: specifically, *Glr*, *Ga*, and *Gs*. In addition, current intelligence batteries do not provide adequate measurement of most specific or narrow CHC abilities, many of which are important in predicting academic achievement (Flanagan et al., 2013). Thus, although there is greater coverage of CHC broad abilities now than there was 5-10 years ago, the need for the XBA approach to assessment remains (Alfonso, et al., 2005).

Application of the XBA Approach

Guiding Principles

In order to ensure that XBA procedures are psychometrically and theoretically sound, it is recommended that practitioners adhere to several guiding principles. These principles are defined briefly in the following paragraphs.

First, select a comprehensive intelligence battery as your core battery in assessment. It is expected that the battery of choice will be one that is deemed most responsive to referral concerns. These batteries may include, but are certainly not limited to the Wechsler Scales, WJ III, SB5, KABC-II, and NEPSY-II. It is important to note that the use of co-normed tests, such as the WJ III tests of cognitive ability and tests of achievement and the KABC-II and KTEA-II, may allow for the widest coverage of broad and narrow CHC abilities and processes.

Second, use subtests and composites from a single battery whenever possible to represent broad CHC abilities. Third, when constructing CHC broad and narrow ability clusters, select tests that have been classified through an acceptable method, such as through CHC theory-driven factor analyses or expert consensus content-validity studies. All test classifications included in the works of Flanagan and colleagues have been classified through these acceptable methods (Flanagan, Ortiz, & Alfonso, 2007, in press; Flanagan et al., 2006). For example, when constructing broad (stratum II) ability composites or clusters, relatively pure CHC indicators should be included (i.e., tests that had either strong or moderate [but not mixed] loadings on their respective factors in theory-driven within- or cross-battery factor analyses). Without empirical classifications of tests, constructs may not be adequately represented and, therefore, inferences about an individual's broad (stratum II) ability cannot be made. Of course, the more broadly an ability is represented (i.e., through the derivation of composites based on multiple qualitatively different narrow ability indicators), the more confidence one has in drawing inferences about that broad ability underlying a composite. A minimum of two qualitatively different indicators per CHC composite is recommended in the XBA approach for practical reasons (viz., time efficient assessment).

Fourth, when at least two qualitatively different indicators of a broad ability of interest are not available on the core battery, then either supplement the core battery with a composite from another battery comprised of at least two qualitatively different indicators of that broad ability or create a cross-battery cluster. For example, if an evaluator is interested in measuring Auditory Processing (*Ga*), and the core battery includes only one or no *Ga* subtests, then select a *Ga* cluster from another battery to supplement the core battery.

Fifth, when crossing batteries (e.g., augmenting a core battery with relevant CHC clusters from another battery) or when deriving CHC broad or narrow ability clusters using tests from different batteries, select tests that were developed and normed within a few years of one another to minimize the effect of spurious differences between test scores that may be attributable to the "Flynn effect" (Flynn, 1984). The XBA software programs developed by Flanagan and colleagues include only those tests that were normed within 10 years of one another (Flanagan et al., 2007, 2013).

Sixth, select tests from the smallest number of batteries to minimize the effect of spurious differences between test scores that may be attributable to differences in the characteristics of independent norm samples (McGrew, 1994). In most cases, using select tests from a single battery to augment the constructs measured by any other major intelligence battery is sufficient to represent the breadth of broad cognitive abilities adequately, as well as to allow for at least two or three qualitatively different narrow ability indicators of most broad abilities (Flanagan et al., 2007). However, in order to measure multiple narrow abilities adequately, more than two batteries will be necessary.

Seventh, establish ecological validity for any and all test performances that are suggestive of normative weaknesses or deficits. The finding of a cognitive weakness or deficit is largely meaningless without evidence of how the weakness manifests in activities of daily living, including academic achievement (Flanagan, Alfonso, & Mascolo, 2011). The validity of test findings is bolstered when clear connections are made between the cognitive dysfunction (as measured by standardized tests) and the educational impact of that dysfunction (e.g., observed in classroom performance or student's work samples).

Step-by-Step Process

The XBA approach can be carried out, using any ability battery as the core instrument in assessment, following six simple steps. These steps are described in detail in Flanagan et al. (2007, 2013), and, therefore, will only be highlighted here.

The first step of the XBA approach involves selecting a comprehensive ability battery that is most conducive to a number of variables, including the age of the child, his or her developmental level and proficiency in English, the specific referral concerns, and so forth. As such, while a test like the WJ III may be appropriate for a relatively bright and articulate seventh-grader who is struggling in math and science, it may not be the best instrument of choice for a third-grader who is an English Language Learner and who is significantly behind her classmates in all academic areas, despite the fact that the WJ III provides the most comprehensive coverage of CHC abilities. This is because many of the WJ III tests have relatively high receptive language demands. In the case of this third-grader, an intelligence battery such as the KABC-II may be more appropriate because its language demands and cultural loadings are generally quite low.

The second step of the XBA approach required that the examiner identify the CHC broad abilities that are adequately measured by the core battery. If the battery does not allow for adequate measurement of the broad and narrow abilities considered most germane in light of the referral, then it will be necessary to supplement the core battery.

The third step requires that the examiner select a supplemental battery that includes measurement of all or nearly all of the abilities that are deemed necessary to address the referral concerns but that are not measured by the core battery. Several examples of how to supplement a core battery to gain a better or more in-depth understanding of CHC broad and narrow abilities can be found in Flanagan and colleagues (2006, 2013).

Step four requires that the examiner administer and score the core and supplemental tests. After administering and scoring the cross-battery assessment, the examiner need only enter obtained scores into an automated program that assists with interpretation. The many benefits of such a program are described in detail in (Flanagan et al., 2007, 2013). The final step, step six, requires that the examiner understand the XBA interpretive guidelines. That is, because the XBA software program provides interpretive statements, it is necessary for the practitioner to have an understanding of how such statements were derived (i.e., underlying program logic). An understanding of the XBA interpretive guidelines will allow the practitioner to make full use of program output.

Although a step-by-step approach to XBA assessment and XBA interpretive software are available, it is important to understand that the XBA approach is not a "cookbook" method for assessment. The XBA principles, procedures, and steps, as well as the XBA software, are intended to guide practitioners systematically through the process of test selection and test interpretation in order to facilitate the implementation of psychometrically and theoretically defensible evaluations. Clinical ingenuity, judgment, and experience remain important and necessary components of competent, defensible, and sound assessment and interpretation practices.

Summary

The XBA approach is a method that allows practitioners to augment or supplement any ability battery to ensure measurement of a wider range of cognitive abilities and neuropsychological processes in a manner consistent with contemporary theory and research. The foundational sources of information upon which the XBA approach was built (i.e., the classifications of ability tests and batteries according to CHC theory) provide a way to systematically construct a more theoretically driven, comprehensive, and valid assessment of cognitive and academic abilities and neuropsychological processes. When the XBA approach is applied to the Wechsler

Intelligence Scales, for example, it is possible to measure important abilities that would otherwise go unassessed (e.g., *Ga*, *Glr*)—abilities that are important in understanding school learning.

The XBA approach allows for the measurement of the cognitive domains specified in CHC and neuropsychological theory with emphasis on those considered most critical on the basis of history, observation, and available test data. The CHC classifications of hundreds of ability tests bring stronger content and construct validity evidence to the evaluation and interpretation process. As test development continues to evolve and becomes increasingly more sophisticated (psychometrically and theoretically), batteries of the future will undoubtedly possess stronger content and construct validity (as Table 2 illustrates). Notwithstanding, it is unrealistic from an economic and practical standpoint to develop a battery that operationalizes contemporary CHC theory fully (Carroll, 1998). Therefore, it is likely that the XBA approach will become increasingly important as the empirical support for CHC theory mounts (Reynolds, Keith, Flanagan, & Alfonso, 2012).

With a strong research base and a multiplicity of CHC and neuropsychological measures available, XBA procedures can aid practitioners in the selective measurement of cognitive constructs that are important with regard to the examinee’s presenting problem(s). In particular, because the XBA approach was developed following important psychometric and validity principles, practitioners are able to address the “disorder in a basic psychological process” component of learning disability more reliably and validly (see Flanagan et al., 2011).

In the past, the lack of theoretical clarity of widely used intelligence tests (e.g., the Wechsler Scales) confounded interpretation and adversely affected the examiner’s ability to draw clear and useful conclusions from the data. The XBA approach has changed the direction of intellectual (cognitive) assessment in several ways. It has aided test authors and publishers in clarifying the theoretical underpinnings of their instruments. It has influenced the interpretation approaches of several commonly used intelligence batteries (e.g., KABC-II, WISC-IV). It has provided a means for understanding the relations between cognitive abilities, neuropsychological processes, and specific academic skills, thereby aiding significantly in the design and interpretation of assessments of individuals suspected of having a learning disability. And, it has assisted in narrowing the gap between theory and practice in assessment-related fields. As a result, measurement and interpretation of human cognitive abilities is guided more by science than clinical acumen.

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Table 1. Parallel Needs in Cognitive Assessment-Related Fields Addressed by the XBA Approach

Need within Assessment-Related Fields[2]	**Need addressed by the XBA Approach**
School Psychology, Clinical Psychology, and Neuropsychology have lagged in the development of conceptual models of the assessment of individuals. There is a need for the development of contemporary models.	The XBA approach provides a contemporary model for measurement and interpretation of cognitive and academic abilities and neuropsychological processes.
It is likely that there is a need for events external to a field of endeavor to give impetus to new developments and real advances in that field.	Carroll and Horn's *Fluid-Crystallized* theoretical models (and more recently Schneider and McGrew's CHC model) and research in cognitive psychology and neuropsychology provided the impetus for and continued refinements to the XBA approach and led to the development of better assessment instruments and interpretive procedures.
There is a need to utilize a conceptual framework to direct any approach to assessment. This would aid in both the selection of instruments and methods, and in the interpretation of test findings.	The XBA approach to assessment is based mainly on CHC theory, but also neuropsychological theory. Since the XBA approach links all the major intelligence and achievement batteries as well as selected neuropsychological instruments to CHC theory, in particular, both selection of tests and interpretation of test findings are made easier.
It is necessary that the conceptual framework or model underlying assessment incorporates various aspects of neuropsychological and cognitive ability function that can be described in terms of constructs which are recognized in the neuropsychological and cognitive psychology literature.	The XBA approach incorporates various aspects of neuropsychological and cognitive ability functions that are described in terms of constructs that are recognized in the literature. In fact, a consistent set of terms and definitions within the CHC literature (e.g., Schneider & McGrew, 2012) and the neuropsychology literature (e.g., Miller, in press) underlie the XBA approach.
There is a need to adopt a conceptual framework that allows for the measurement of the full range of behavioral functions subserved by the brain. Unfortunately, in neuropsychological assessment there is no inclusive set of measures which is standardized on a single normative population.	XBA assessment allows for the measurement of a wide range of broad and narrow cognitive abilities specified in CHC theory and neuropsychological processes specified by neuropsychology theory and research. Although an XBA norm group does not exist, the crossing of batteries and the interpretation of assessment results are based on sound psychometric principles and procedures.

[2] Information obtained, in part, from Wilson, B.C. (1992). The neuropsychological assessment of the preschool child: A branching model. In I. Rapin & S.I. Segalowitz (Eds.), *Handbook of neuropsychology: Child neuropsychology* (Vol. 6) (pp. 377-394).

Because there are no truly unidimensional measures in psychological assessment, there is a need to select subtests from standardized instruments which appear to reflect the neurocognitive function of interest. In neuropsychological assessment, the aim, therefore, is to select those measures that, on the basis of careful task analysis, appear mainly to tap a given construct.	The XBA approach is defined, in part, by a CHC classification system. The majority of subtests from the major intelligence and achievement batteries as well as selected neuropsychological instruments were classified empirically as measures of broad and narrow CHC constructs (either via CHC within- or cross-battery factor analysis or expert consensus or both). In addition, the subtests of intelligence and neuropsychological batteries were classified according to several neuropsychological domains (e.g., attention, visual-spatial, auditory-verbal, speed and efficiency, executive). Use of evidence-based classifications allows practitioners to be reasonably confident that a given test taps a given construct.
It is clear that an eclectic approach is needed in the selection of measures, preferably subtests rather that the omnibus IQs, in order to gain more specificity in the delineation of patterns of function and dysfunction.	The XBA approach ensures that two or more relatively pure, but qualitatively different, indicators of each *broad* cognitive ability are represented in a complete assessment. Two or more qualitatively similar indicators are necessary to make inferences about specific or *narrow* CHC abilities. This process is eclectic in its selection of measures.
There is a need to solve the potential problems that can arise from crossing normative groups as well as sets of measures that vary in reliability.	In the XBA approach, one can typically achieve baseline data in cognitive functioning across seven to nine CHC broad abilities through the use of only two well-standardized batteries, which minimizes the effects of error due to norming differences. Also, since interpretation of both broad and narrow CHC abilities is made at the cluster (rather than subtest) level, issues related to low reliability are less problematic in this approach. Finally, because cross-battery clusters are generated using estimated median reliabilities and intercorrelations, the data yielded by this approach is psychometrically sound.

Table 3. Impact of CHC Theory and XBA CHC Classifications on Intelligence Test Development

Test (Year of Publication) CHC and XBA Impact	**Revision (Year of Publication)** CHC and XBA Impact
K-ABC (1983) No obvious impact.	**KABC-II (2004)** Provided a second global score that include fluid and crystallized abilities; Included several new subtests measuring reasoning; Interpretation of test performance may be based on CHC theory or Luria's theory; Provided assessment of five CHC broad abilities.
SB:FE (1986) Used a three-level hierarchical model of the structure of cognitive abilities to guide construction of the test: the top level included 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)** Used CHC theory to guide test development; Increased the number of broad factors from 4 to 5; Included a Working Memory Factor based on research indicating its importance for academic success.
WPPSI-R (1989) No obvious impact.	**WPPSI-III (2002)** Incorporated measures of Processing Speed that yielded a Processing Speed Quotient based on recent research indicating the importance of processing speed for early academic success; Enhanced the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests.
WJ-R (1989) Used modern *Gf-Gc* theory as the cognitive model for test development; Included two measures of each of eight broad abilities.	**WJ III (2001; Normative Update, 2007)** Used CHC theory as a "blueprint" for test development; Included 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)** Eliminated Verbal and Performance IQs; Replaced the Freedom from Distractibility Index with the Working Memory Index;

	Replaced the Perceptual Organization Index with the Perceptual Reasoning Index; Enhanced the measurement of fluid reasoning by adding Matrix Reasoning and Picture Concepts; Enhanced measurement of Processing Speed with the Cancellation subtest.
DAS (1990) No obvious impact.	**DAS-II (2007)** CHC broad abilities are represented in the DAS-II subtests and composites
WAIS-III (1997) No obvious impact.	**WAIS-IV (2008)** Eliminated Verbal and Performance IQs; Replaced the Perceptual Organization Index with the Perceptual Reasoning Index; Enhanced the measurement of fluid reasoning by adding the Figure Weights and Visual Puzzles subtests; Enhanced measurement of Processing Speed with the Cancellation subtest. Enhanced measurement of memory with the Working Memory Index.
WPPSI-III (2002) Incorporated measures of Processing Speed that yielded a Processing Speed Quotient based on recent research indicating the importance of processing speed for early academic success; Enhanced the measurement of fluid reasoning by adding the Matrix Reasoning and Picture Concepts subtests.	**WPPSI-IV (2012)** Eliminated Verbal and Performance IQs; Enhanced measures of working memory, processing speed and inhibitory control; Updated studies on the relationship to other measures including WPPSI–III, WISC–IV, Bayley-III, DAS-II, WIAT-III and select NEPSY-2 subtests, indicating the importance of understanding how these abilities are interrelated.

Note. K-ABC = Kaufman Assessment Battery for Children (Kaufman & Kaufman, 1983); KABC-II = Kaufman Assessment Battery for Children-Second Edition (Kaufman & Kaufman, 2004); SB:FE = Stanford-Binet Intelligence Scale-Fourth Edition (Thorndike, Hagen, & Sattler, 1986); SB5 = Stanford-Binet Intelligence Scales-Fifth Edition (Roid, 2003); WAIS-III = Wechsler Adult Intelligence Scale-Third Edition (Wechsler, 1997); WAIS-Iv = Wechsler Adult Intelligence scale-Forth Edition (Wechsler, 2008); 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); KAIT = Kaufman Adolescent and Adult Intelligence Test (Kaufman & Kaufman 1993); DAS = Differential Ability Scales (Elliott, 1990); DAS-II = Differential Ability Scales-Second Edition (Elliott, 2007).