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INTRODUCTION TO THE SPECIAL ISSUE: CURRENT RESEARCH IN CATTELL–HORN–CARROLL–BASED ASSESSMENT

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The construct (or concept) of intelligence and the development of tests to assess it have a long and varied history. The first applied intelligence tests consisted of unidimensional static measures of general intelligence (*g*) (Kaufman, 2009), and the first practical measure of intelligence was published by Alfred Binet and Theodore Simon in 1905. The intent of Binet's test was to differentiate between retarded (intellectually disabled) and normal school children. Early intelligence tests were also used to identify individuals who were gifted and talented (e.g., Hollingsworth, 1926; Terman, 1925). Following the development of early *g*-based intelligence tests, a lengthy period of time elapsed during which intelligence test development was prominent and psychometrically driven research on the structure of intelligence was extensive. These activities have culminated in today's multidimensional intelligence tests (see Kaufman, 2009, for a historical overview).

More specific to the field of school psychology, measures of intelligence have traditionally been considered to be a necessary component (i.e., ability–achievement discrepancy) in the identification of children with specific learning disabilities (SLDs) as prescribed by P.L. 94-142 (Flanagan & Harrison, 2005) and intellectual disabilities (IDs). Recent changes in SLD criteria in the reauthorization of the Individuals with Disabilities Education Act (IDEA) have significantly impacted the practice of intelligence testing—to the point that the efficacy of intelligence testing is now being questioned (Dombrowski, Kamphaus, & Reynolds, 2004; Fletcher, Coulter, Reschly, & Vaughn, 2004; Fletcher & Reschly, 2005; Gresham, Restori, & Cook, 2008). In particular, the recent emphasis on Response to Intervention (RTI) as a potential method of determining SLD eligibility has led to serious questions about the usefulness, necessity, empirical support, and efficacy of individualized intelligence or cognitive ability testing within educational settings.

It is within this context that the focus of the current special issue was developed. The purpose of this issue is to "take stock" of the usefulness of intelligence theory and testing within the emerging new special education landscape, with a particular focus on the contribution of the contemporary Cattell–Horn–Carroll (CHC) theory of cognitive abilities.

Shifting Sands: The Changing Assessment Landscape

The IDEA-driven RTI movement has significantly impacted the field of school psychology. This impact is evident from increased examination in school psychology literature of alternative measurement approaches (e.g., curriculum-based measures and progress-monitoring tools) and/or lack of response to intervention for special education eligibility (Glover & DiPerna, 2007; Reschly, 2005; Shinn, 2007). Some authors (Dehn, 2008; Hale, Kaufman, Naglieri, & Kavale, 2006; Mather & Gregg, 2006; Naglieri & Kaufman, 2008; Witsken, Stoeckel, & D'Amato, 2008) have advocated, however, for the continued use of intelligence tests within the RTI framework to increase our

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understanding of the unique psychoeducational needs of students, which in turn should contribute to the formation of individualized educational planning. It is important to note, however, that supporters of cognitive testing within the RTI framework argue that school psychologists should focus less on the overall full-scale IQ, be more selective and focused in their assessments, and examine profiles of CHC cognitive abilities to better understand strengths and weaknesses (Fiorello, Hale, & Snyder, 2006; Hale, Naglieri, Kaufman, & Kavale, 2004; Kavale & Flanagan, 2007; Mather & Wendling, 2005).

We believe, as do the authors of articles in this special issue, that intelligence testing will continue to be a necessary component of a school psychologist's repertoire of professional skills. However, the "one-complete-standard-battery-fits-all" approach to cognitive testing may no longer be efficient nor appropriate. Rather, as first articulated by Kaufman (1979), "intelligent" intelligence testing appears to be necessary in the new IDEA RTI assessment environment as school psychologists need to be familiar with the ability of each existing battery to validly measure a child's cognitive strengths and weaknesses. For cognitive ability testing to make a difference in the lives of school-age children, psychologists need to use instruments based on the best evidence from intelligence research and theory.

The contemporary CHC theory has emerged as the cognitive taxonomy with the largest body of supporting evidence (Kaufman, 2009; McGrew, 2005). Evidence for the importance of this theory can be seen in a recently invited editorial (by a school psychologist) on CHC theory in the prestigious journal *Intelligence* (McGrew, 2009). More importantly, CHC theory "has formed the foundation for most contemporary IQ tests" (Kaufman, 2009, p. 91).

CHC Theory Briefly Described

The CHC theory of cognitive abilities is a hierarchical model of intelligence that combines the Cattell–Horn *Gf-Gc* (Horn, 1989) and the Carroll (1993) three-stratum models of human cognitive abilities (see McGrew, 2005, 2009; also see Kaufman, 2009). Carroll expanded on the Cattell–Horn *Gf-Gc* theory and proposed a three-stratum model that contains more than 70 narrow abilities at stratum one, eight broad second-order abilities at stratum two, and an overall *g* ability (general intelligence) at stratum three. The broad CHC abilities measured by contemporary intelligence batteries include fluid reasoning (*Gf*), comprehension–knowledge (*Gc*), visuospatial ability (*Gv*), long-term storage and retrieval (*Glr*), auditory processing (*Ga*), cognitive processing speed (*Gs*), short-term memory (*Gsm*), and quantitative knowledge (*Gq*) and/or reasoning (*Gf*). Definitions of the broad CHC abilities, the narrow abilities subsumed under each domain, as well as additional abilities (e.g., tactile abilities [Gh]) now considered part of a more comprehensive CHC human ability model (McGrew, 2009), are presented in Table 1.[i]

The Emergence of CHC Theory, Test Instruments, and School-Related Research

Contemporary CHC intelligence test development, interpretation, and applied research can be traced to a fortuitous meeting of Richard Woodcock, John Horn, and John "Jack" Carroll in the fall of 1986, a meeting also attended by the second author of this introductory article (McGrew, 2005). This meeting resulted in the 1989 publication of the first individually administered, nationally standardized CHC-based intelligence battery,[ii] the Woodcock-Johnson Psychoeducational

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[i] All authors of articles in this special issue were asked to use Table 1 as the official set of CHC definitions in their articles. This request was made to save space and to add consistency of interpretation across all articles in this issue.

[ii] As noted by McGrew (2005), early CHC research was labeled as Gf-Gc theory, which eventually became known as CHC theory. To eliminate confusion, the label CHC is used throughout this article even when referencing many of the "First Generation Gf-Gc Assessment" activities and publications (see McGrew, 2005, 2009).

Table 1
CHC Broad and Narrow Cognitive Ability Definitions

Fluid reasoning (*Gf*): The use of deliberate and controlled mental operations, often in a flexible manner, to solve novel problems that cannot be performed automatically. Mental operations often include drawing inferences, concept formation, classification, generalization, generating and testing hypothesis, identifying relations, comprehending implications, problem solving, extrapolating, and transforming information. Inductive and deductive reasoning are generally considered the hallmark indicators of *Gf*. *Gf* has been linked to cognitive complexity, which is typically defined as the greater use of a wide and diverse array of elementary cognitive processes during performance. Historically is often referred to as fluid intelligence.

General Sequential (deductive) Reasoning (RG): Ability to start with stated assertions (rules, premises, or conditions) and to engage in one or more steps leading to a problem solution. The processes are deductive as evidenced in the ability to reason and draw conclusions from given general conditions or premises to the specific. Often known as hypothetico-deductive reasoning.

Induction (I): Ability to discover the underlying characteristic (e.g., rule, concept, principle, process, trend, class membership) that underlies a specific problem or a set of observations or to apply a previously learned rule to the problem. Reasoning from specific cases or observations to general rules or broad generalizations. Often requires the ability to combine separate pieces of information in the formation of inferences, rules, hypotheses, or conclusions.

Quantitative Reasoning (RQ): Ability to inductively (I) and/or deductively (RG) reason with concepts involving mathematical relations and properties.

Piagetian Reasoning (RP): Ability to demonstrate the acquisition and application (in the form of logical thinking) of cognitive concepts as defined by Piaget's developmental cognitive theory. These concepts include seriation (organizing material into an orderly series that facilitates understanding of relations between events), conservation (awareness that physical quantities do not change in amount when altered in appearance), classification (ability to organize materials that possess similar characteristics into categories), and so forth.

Speed of Reasoning (RE): Speed or fluency in performing reasoning tasks (e.g., quickness in generating as many possible rules, solutions, etc., to a problem) in a limited time. Also listed under *Gs*.

Comprehension-Knowledge (*Gc*): The knowledge of the culture that is incorporated by individuals vis-à-vis a process of acculturation. *Gc* is typically described as a person's breadth and depth of acquired knowledge of the language, information, and concepts of a specific culture and/or the application of this knowledge. *Gc* is primarily a store of verbal or language-based declarative (knowing *what*) and procedural (knowing *how*) knowledge acquired through the investment of other abilities during formal and informal educational and general life experiences. Historically it is often referred to as crystallized intelligence.

Language Development (LD): General development or understanding and application of words, sentences, and paragraphs (not requiring reading) in spoken native language skills to express or communicate a thought or feeling.

Lexical Knowledge (VL): Extent of vocabulary (nouns, verbs, or adjectives) that can be understood in terms of correct word (semantic) meanings. Although evidence indicates that vocabulary knowledge is a separable component from LD, it is often difficult to disentangle these two highly connected and corrected abilities in research studies.

Listening Ability (LS): Ability to listen and understand the meaning of oral communications (spoken words, phrases, sentences, and paragraphs). The ability to receive and understand spoken information.

General (verbal) Information (K0): Range of general stored knowledge (primarily verbal).

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

Communication Ability (CM): Ability to speak in "real life" situations (e.g., conversation, lecture, group participation) in a manner that transmits ideas, thoughts, or feelings to one or more individuals.

Oral Production and Fluency (OP): More specific or narrow oral communication skills than reflected by CM. Poorly defined by current research.

Grammatical Sensitivity (MY): Knowledge or awareness of the distinctive features and structural principles of a native language that allows for the construction of words (morphology) and sentences (syntax). Does not include the skill in applying this knowledge.

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Foreign Language Proficiency (KL): Similar to LD but for a foreign language.

Foreign Language Aptitude (LA): Rate and ease of learning a new language.

General (domain-specific) knowledge (*Gkn*): The breadth, depth, and mastery of a person's acquired knowledge in specialized (demarcated) subject matter or discipline domains that typically do not represent the general universal experiences of individuals in a culture (*Gc*). *Gkn* reflects deep specialized knowledge domains developed through intensive systematic practice and training (over an extended period of time) and the maintenance of the knowledge base through regular practice and motivated effort (a.k.a., expertise).

Knowledge of English as a Second Language (KE): Degree of knowledge of English as a second language.

Knowledge of Signing (KF): Knowledge of finger-spelling and signing (e.g., American Sign Language [ASL]) used in communication with the deaf or hard of hearing.

Skill in Lip-Reading (LP): Competence in the ability to understand communication from others by watching the movement of their mouths and expressions (lip reading). Also known as speech reading.

Geography Achievement (A5): Range of geography knowledge (e.g., capitals of countries).

General Science Information (K1): Range of stored scientific knowledge (e.g., biology, physics, engineering, mechanics, electronics).

Mechanical Knowledge (MK): Knowledge about the function, terminology, and operation of ordinary tools, machines, and equipment. Because these factors were identified in research prior to the information/technology explosion, it is unknown if this ability generalizes to the use of modern technology (e.g., faxes, computers, Internet).

Knowledge of Behavioral Content (BC): Knowledge or sensitivity to nonverbal human communication/interaction systems (beyond understanding sounds and words, e.g., facial expressions and gestures) that communicate feelings, emotions, and intentions, most likely in a culturally patterned style.

Visual processing (*Gv*): The ability to generate, store, retrieve, and transform visual images and sensations. *Gv* abilities are typically measured by tasks (viz., figural or geometric stimuli) that require the perception and transformation of visual shapes, forms, images, and/or tasks that require maintaining spatial orientation with regard to objects that may change or move through space.

Visualization (Vz): The ability to apprehend a spatial form, object, or scene and match it with another spatial object, form, or scene with the requirement to rotate it (one or more times) in two or three dimensions. Requires the ability to mentally imagine, manipulate, or transform objects or visual patterns (without regard to speed of responding) and to "see" (predict) how they would appear under altered conditions (e.g., parts are moved or rearranged). Differs from Spatial Relations (SR) primarily by a de-emphasis on fluency.

Spatial Relations (SR): Ability to rapidly perceive and manipulate (mental rotation, transformations, reflection, etc.) visual patterns or to maintain orientation with respect to objects in space. SR may require the identification of an object when viewed from different angles or positions.

Closure Speed (CS): Ability to quickly identify a familiar meaningful visual object from incomplete (e.g., vague, partially obscured, disconnected) visual stimuli, without knowing in advance what the object is. The target object is assumed to be represented in the person's long-term memory store. The ability to "fill in" unseen or missing parts in a disparate perceptual field and form a single percept.

Flexibility of Closure (CF): Ability to identify a visual figure or pattern embedded in a complex distracting or disguised visual pattern or array, when knowing in advance what the pattern is. Recognition of, yet the ability to ignore, distracting background stimuli is part of the ability.

Visual Memory (MV): Ability to form and store a mental representation or image of a visual shape or configuration (typically during a brief study period), over at least a few seconds, and then recognize or recall it later (during the test phase).

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Spatial Scanning (SS): Ability to quickly and accurately survey (visually explore) a wide or complicated spatial field or pattern and identify a particular configuration (path) through the visual field. Usually requires visually following the indicated route or path through the visual field.

Serial Perceptual Integration (PI): Ability to identify (and typically name) a pictorial or visual pattern when parts of the pattern are presented rapidly in serial order (e.g., portions of a line drawing of a dog are passed in sequence through a small "window").

Length Estimation (LE): Ability to accurately estimate or compare visual lengths or distances without the aid of measurement instruments.

Perceptual Illusions (IL): The ability to resist being affected by the illusory perceptual aspects of geometric figures (i.e., not forming a mistaken perception in response to some characteristic of the stimuli). May best be thought of as a person's "response tendency" to resist perceptual illusions.

Perceptual Alternations (PN): Consistency in the rate of alternating between different visual perceptions.

Imagery (IM): Ability to mentally depict (encode) and/or manipulate an object, idea, event, or impression (that is not present) in the form of an abstract spatial form. Separate IM level and rate (fluency) factors have been suggested.

Auditory processing (*Ga*): Abilities that depend on sound as input and on the functioning of our hearing apparatus. A key characteristic is the extent to which an individual can cognitively control (i.e., handle the competition between signal and noise) the perception of auditory information. The *Ga* domain circumscribes a wide range of abilities involved in the interpretation and organization of sounds, such as discriminating patterns in sounds and musical structure (often under background noise and/or distorting conditions) and the ability to analyze, manipulate, comprehend, and synthesize sound elements, groups of sounds, or sound patterns.

Phonetic Coding (PC): Ability to code, process, and be sensitive to nuances in phonemic information (speech sounds) in *Gsm*. Includes the ability to identify, isolate, blend, or transform sounds of speech. Frequently referred to as phonological or phonemic awareness.

Speech Sound Discrimination (US): Ability to detect and discriminate differences in phonemes or speech sounds under conditions of little or no distraction or distortion.

Resistance to Auditory Stimulus Distortion (UR): Ability to overcome the effects of distortion or distraction when listening to and understanding speech and language. It is often difficult to separate UR from US in research studies.

Memory for Sound Patterns (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 their fundamental attributes (i.e., pitch, intensity, duration, and rhythm).

Temporal Tracking (UK): Ability to mentally track auditory temporal (sequential) events so as to be able to count, anticipate, or rearrange them (e.g., reorder a set of musical tones). According to Stankov (2000), UK may represent the first recognition of the ability (Stankov & Horn, 1980) that is now interpreted as working memory (MW).

Musical Discrimination and Judgment (U1 U9): Ability to discriminate and judge tonal patterns in music with respect to melodic, harmonic, and expressive aspects (phrasing, tempo, harmonic complexity, intensity variations).

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.

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Table 1
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Gsm: The ability to apprehend and maintain awareness of a limited number of elements of information in the immediate situation (events that occurred in the last minute or so). A limited-capacity system that loses information quickly through the decay of memory traces, unless an individual activates other cognitive resources to maintain the information in immediate awareness.

Memory Span (MS): Ability to attend to, register, and immediately recall (after only one presentation) temporally ordered elements and then reproduce the series of elements in correct order.

Working Memory (MW): Ability to temporarily store and perform a set of cognitive operations on information that requires divided attention and the management of the limited capacity resources of *Gsm*. Is largely recognized to be the mind's "scratchpad" and consists of up to four subcomponents. The phonological or articulatory loop processes auditory–linguistic information whereas the visuospatial sketch/scratchpad is the temporary buffer for visually processed information. The central executive mechanism coordinates and manages the activities and processes in working memory. The most recent component added to the model is the episodic buffer. Recent research (see McGrew, 2005) suggests that MW is not of the same nature as the other 60+ narrow factor-based, traitlike individual difference constructs included in this table. MW is a theoretically developed construct (proposed to explain memory findings from experimental research) and not a label for an individual-differences type factor. MW is retained in the current CHC taxonomy table as a reminder of the importance of this construct in understanding new learning and performance of complex cognitive tasks (see McGrew, 2005).

Long-term storage and retrieval (*Glr*): The ability to store and consolidate new information in long-term memory and later fluently retrieve the stored information (e.g., concepts, ideas, items, names) through association. Memory consolidation and retrieval can be measured in terms of information stored for minutes, hours, weeks, or longer. Some *Glr* narrow abilities have been prominent in creativity research (e.g., production, ideational fluency, or associative fluency).

Associative Memory (MA): Ability to recall one part of a previously learned but unrelated pair of items (that may or may not be meaningfully linked) when the other part is presented (e.g., paired-associative learning).

Meaningful Memory (MM): Ability to note, retain, and recall information (set of items or ideas) when there is a meaningful relation between the bits of information, the information comprises a meaningful story or connected discourse, or the information relates to existing contents of memory.

Free Recall Memory (M6): Ability to recall (without associations) as many unrelated items as possible, in any order, after a large collection of items is presented (each item presented singly). Requires the ability to encode a "superspan collection of material" (Carroll, 1993, p. 277) that cannot be kept active in short-term or working memory.

Ideational Fluency (FI): Ability to rapidly produce a series of ideas, words, or phrases related to a specific condition or object. Quantity, not quality or response originality, is emphasized. The ability to think of a large number of different responses when a prescribed task requires the generation of numerous responses. The ability to call up ideas.

Associational Fluency (FA): A highly specific ability to rapidly produce a series of words or phrases associated in meaning (semantically associated; or some other common semantic property) when given a word or concept with a restricted area of meaning. In contrast to Ideational Fluency (FI), quality rather quantity of production is emphasized.

Expressional Fluency (FE): Ability to rapidly think of and organize words or phrases into meaningful complex ideas under general or more specific cued conditions. Requires the production of connected discourse in contrast to the production of isolated words (e.g., FA FW). Differs from FI in the requirement to rephrase given ideas rather than generating new ideas. The ability to produce different ways of saying much the same thing.

Naming Facility (NA): Ability to rapidly produce accepted names for concepts or things when presented with the thing itself or a picture of it (or cued in some other appropriate way). The naming responses must be in an individual's long-term memory store (i.e., objects or things to be named have names that are familiar to the individual). In contemporary reading research, this ability is called rapid automatic naming (RAN).

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Word Fluency (FW): Ability to rapidly produce isolated words that have specific phonemic, structural, or orthographic characteristics (independent of word meanings). Has been mentioned as possibly being related to the "tip-of-the-tongue" phenomenon (e.g., word finding difficulties; Carroll, 1993). One of the first fluency abilities identified (Eckstrom et al., 1979).

Figural Fluency (FF): Ability to rapidly draw or sketch as many things (or elaborations) as possible when presented with a nonmeaningful visual stimulus (e.g., set of unique visual elements). Quantity is emphasized over quality or uniqueness.

Figural Flexibility (FX): Ability to rapidly change set and try out a variety of approaches to solutions for figural problems that have several stated criteria. Fluency in successfully dealing with figural tasks that require a variety of problem-solving approaches.

Sensitivity to Problems (SP): Ability to rapidly think of a number of alternative solutions to practical problems (e.g., what can people do to stay healthy?). More broadly may be considered the "ability to imagine problems associated with function or change of function of objects and to suggest ways to deal with these problems" Royce (1973). Requires the recognition of the existence of a problem.

Originality/Creativity (FO): Ability to rapidly produce unusual, original, clever, divergent, or uncommon responses (expressions, interpretations) to a given topic, situation, or task. The ability to invent unique solutions to problems or to develop innovative methods for situations in which a standard operating procedure does not apply. Following a new and unique path to a problem's solution. FO differs from FI in that FO focuses on the quality of creative responses whereas FI focuses on an individual's ability to think of a large number of different responses.

Learning Abilities (L1): General learning ability rate. Poorly defined by existing research.

Processing Speed (*Gs*): The ability to automatically and fluently perform relatively easy or overlearned elementary cognitive tasks, especially when high mental efficiency (i.e., attention and focused concentration) is required.

Perceptual Speed (P): Ability to rapidly and accurately search, compare (for visual similarities or differences), and identify visual elements presented side by side or separated in a visual field. Recent research (Ackerman et al., 2002; Ackerman & Cianciolo, 2000; Ackerman & Kanfer, 1993; see McGrew, 2005) suggests that P may be an intermediate stratum ability (between narrow and broad) defined by four narrow subabilities: (1) Pattern Recognition*(Ppr)*—the ability to quickly recognize simple visual patterns; (2) Scanning *(Ps)*—the ability to scan, compare, and look up visual stimuli; (3) Memory *(Pm)*—the ability to perform visual perceptual speed tasks that place significant demands on immediate *Gsm,* and (d) Complex *(Pc)*—the ability to perform visual pattern recognition tasks that impose additional cognitive demands, such as spatial visualization, estimating and interpolating, and heightened memory span loads.

Rate-of-Test-Taking (R9): Ability to rapidly perform tests that are relatively easy or overlearned (require very simple decisions). This ability is not associated with any particular type of test content or stimuli. May be similar to a higher-order "psychometric time" factor (Roberts & Stankov, 1999; Stankov, 2000). Recent research has suggested that R9 may be better classified as an intermediate (between narrow and broad strata) ability that subsumes most all psychometric speeded measures (see McGrew, 2005).

Number Facility (N): Ability to rapidly perform basic arithmetic (i.e., add, subtract, multiply, divide) and accurately manipulate numbers quickly. N does not involve understanding or organizing mathematical problems and is not a major component of mathematical/quantitative reasoning or higher mathematical skills.

Speed of Reasoning (RE): Speed or fluency in performing reasoning tasks (e.g., quickness in generating as many possible rules, solutions, etc., to a problem) in a limited amount of time. Also listed under *Gf.*

Reading Speed (fluency) (RS): Ability to silently read and comprehend connected text (e.g., a series of short sentences; a passage) rapidly and automatically (with little conscious attention to the mechanics of reading). Also listed under *Grw.*

Writing Speed (fluency) (WS): Ability to correctly copy words or sentences repeatedly or write words, sentences, or paragraphs, as quickly as possible. Also listed under *Grw* and *Gps*.

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Table 1
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Reaction and decision speed (*Gt*): The ability to make elementary decisions and/or responses (simple reaction time) or one of several elementary decisions and/or responses (complex reaction time) at the onset of simple stimuli. *Gt* is typically measured by chronometric measures of reaction and inspection time.

Simple Reaction Time (R1): Reaction time (in milliseconds) to the onset of a single stimulus (visual or auditory) that is presented at a particular point of time. R1 frequently is divided into the phases of decision time (DT; the time to decide to make a response and the finger leaves a home button) and movement time (MT; the time to move finger from the home button to another button where the response is physically made and recorded).

Choice Reaction Time (R2): Reaction time (in milliseconds) to the onset of one of two or more alternative stimuli, depending on which alternative is signaled. Similar to R1, can be decomposed into DT and MT. A frequently used experimental method for measuring R2 is the Hick paradigm.

Semantic Processing Speed (R4): Reaction time (in milliseconds) when a decision requires some encoding and mental manipulation of the stimulus content.

Mental Comparison Speed (R7): Reaction time (in milliseconds) where stimuli must be compared for a particular characteristic or attribute.

Inspection Time (IT): The ability to quickly (in milliseconds) detect change or discriminate between alternatives in a briefly displayed stimulus (e.g., two vertical lines of different size joined horizontally across the top).

Psychomotor speed (*Gps*): The ability to rapidly and fluently perform physical body motor movements (e.g., movement of fingers, hands, legs) largely independent of cognitive control.

Speed of Limb Movement (R3): The ability to make rapid specific or discrete motor movements of the arms or legs (measured after the movement is initiated). Accuracy is not important.

Writing Speed (fluency) (WS): The ability to copy correctly words or sentences repeatedly or write words, sentences, or paragraphs, as quickly as possible. Also listed under *Grw* and *Gps*.

Speed of Articulation (PT): Ability to rapidly perform successive articulations with the speech musculature.

Movement Time (MT): Recent research (see summaries by Deary, 2003; Nettelbeck, 2003; also see McGrew, 2005) suggests that MT may be an intermediate stratum ability (between narrow and broad strata) that represents the second phase of reaction time as measured by various elementary cognitive tasks (ECTs). The time taken to physically move a body part (e.g., a finger) to make the required response is movement time (MT). MT may also measure the speed of finger, limb, or multilimb movements or vocal articulation (diadochokinesis; Greek for "successive movements") (Carroll, 1993; Stankov, 2000) and is also listed under *Gt*.

***Gq*:** The breadth and depth of a person's acquired store of declarative and procedural quantitative or numerical knowledge. *Gq* is largely acquired through the investment of other abilities primarily during formal educational experiences. *Gq* represents an individual's store of acquired mathematical knowledge, not reasoning with this knowledge. Factor analysis research has been limited in this domain and other *Gq* narrow abilities most likely exist (e.g., dimensions of early number sense or literacy).

Mathematical Knowledge (KM): Range of general knowledge about mathematics. Not the performance of mathematical operations or the solving of math problems.

Mathematical Achievement (A3): Measured (tested) mathematics achievement.

Reading and writing (*Grw*): The breadth and depth of a person's acquired store of declarative and procedural reading and writing skills and knowledge. *Grw* includes both basic skills (e.g., reading and spelling of single words) and the ability to read and write complex connected discourse (e.g., reading comprehension and the ability to write a story).

Reading Decoding (RD): Ability to recognize and decode words or pseudowords in reading using a number of subabilities (e.g., grapheme encoding, perceiving multiletter units, and phonemic contrasts).

Reading Comprehension (RC): Ability to attain meaning (comprehend and understand) connected discourse during reading.

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Table 1
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Verbal (printed) Language Comprehension (V): General development or the understanding of words, sentences, and paragraphs in one's native language, as measured by reading vocabulary and reading comprehension tests. Does not involve writing, listening to, or understanding spoken information.

Cloze Ability (CZ): Ability to read and supply missing words (that have been systematically deleted) from prose passages. Correct answers can be supplied only if the person understands (comprehends) the meaning of the passage.

Spelling Ability (SG): Ability to form words with the correct letters in accepted order (spelling).

Writing Ability (WA): Ability to communicate information and ideas in written form so that others can understand (with clarity of thought, organization, and good sentence structure). Is a broad ability that involves a number of other writing subskills (e.g., knowledge of grammar, the meaning of words, and how to organize sentences or paragraphs).

English Usage Knowledge (EU): Knowledge of the "mechanics" (capitalization, punctuation, usage, and spelling) of written and spoken English language discourse.

Reading Speed (fluency) (RS): Ability to silently read and comprehend connected text (e.g., a series of short sentences; a passage) rapidly and automatically (with little conscious attention to the mechanics of reading). Also listed under *Gs*.

Writing Speed (fluency) (WS): Ability to copy words or sentences repeatedly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under *Gs* and *Gps*.

Psychomotor abilities (*Gp*): The ability to perform physical body motor movements (e.g., movement of fingers, hands, legs) with precision, coordination, or strength. Movement or motor behaviors are typically the result of mental activity.

Static Strength (P3): The ability to exert muscular force to move (push, lift, pull) a relatively heavy or immobile object.

Multilimb Coordination (P6): The ability to make quick specific or discrete motor movements of the arms or legs (measured after the movement is initiated). Accuracy is not relevant.

Finger Dexterity (P2): The ability to make precisely coordinated movements of the fingers (with or without the manipulation of objects).

Manual Dexterity (P1): Ability to make precisely coordinated movements of a hand or a hand and the attached arm.

Arm-Hand Steadiness (P7): The ability to precisely and skillfully coordinate arm–hand positioning in space.

Control Precision (P8): The ability to exert precise control over muscle movements, typically in response to environmental feedback (e.g., changes in speed or position of object being manipulated).

Aiming (AI): The ability to precisely and fluently execute a sequence of eye–hand coordination movements for positioning purposes.

Gross Body Equilibrium (P4): The ability to maintain the body in an upright position in space or regain balance after balance has been disturbed.

Olfactory abilities (*Go*): Abilities that depend on sensory receptors of the main olfactory system (nasal chambers). The cognitive and perceptual aspects of this domain have not yet been widely investigated.

Olfactory Memory (OM): Memory for odors (smells).

Olfactory Sensitivity (OS): Sensitivity to different odors (smells).

Tactile abilities (*Gh*): Abilities involved in the perception and judging of sensations that are received through tactile (touch) sensory receptors. Includes abilities involved in the judgment of thermal stimulation, spatial stimulation, or patterns imposed on the skin. The cognitive and perceptual aspects of this domain have not yet been widely investigated.

Tactile Sensitivity (TS): The ability to detect and make fine discriminations of pressure on the surface of the skin.

(*Continued*)

Table 1
Continued

Kinesthetic abilities (*Gk*): Abilities that depend on sensory receptors that detect bodily position, weight, or movement of the muscles, tendons, and joints. Abilities involved in the process of controlling and coordinating body movements, including walking, talking, facial expressions, gestures, and posture. The cognitive and perceptual aspects of this domain have not yet been widely investigated.
Kinesthetic Sensitivity (KS): The ability to detect, or be aware, of movements of the body or body parts, including the movement of upper body limbs (arms) and the ability to recognize a path the body previously explored without the aid visual input (blindfolded).

Note. Many of the ability definitions in this table, or portions thereof, were originally published in McGrew (1997), which in turn, were developed from a detailed reading of *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. The two-letter narrow (stratum I) ability factor codes (e.g., RG), as well as most of the broad ability factor codes (e.g., *Gf*) are from Carroll (1993). McGrew's (1997) definitions have been revised and extended here based on a review of a number of additional sources. Primary sources included Carroll (1993), Corsini (1999), Ekstrom et al. (1979), Fleishman & Quaintance (1984), and Sternberg (1994). The broad ability definitions included in this table are from McGrew (2009).

Battery–Revised (WJ-R; McGrew, Werder, & Woodcock, 1991). This landmark event, which occurred 20 years ago, provided the impetus for the major CHC-driven evolution of school-based intelligence-testing practice. A second historical meeting occurred in 1999 in Chapel Hill, North Carolina, where the authors and publisher of the Woodcock–Johnson III Tests of Cognitive Abilities (WJ-III) and the Stanford–Binet Intelligence Scales, Fifth Edition (SB5), met with both John Horn and Jack Carroll. The outcome was an informal agreement between Horn and Carroll to characterize their similar theories under the umbrella of the "Cattell–Horn–Carroll (CHC) theory of cognitive abilities" (McGrew, 2005). The importance of these two meetings was recently recognized by Kaufman (2009) when he stated:

> Talk about the tail wagging the dog! What had begun back in the late 1970s and early 1980s as a search for the best theories on which to building an IQ test had come full circle: Two decades later, the needs of test publishers and test authors forged the theory that underlies almost all current-day IQ tests (p. 99).

Subsequent important CHC events followed during this 20-year period, and included (a) the first set of CHC-organized joint test battery factor analysis studies (Woodcock, 1990; see Keith & Reynolds, this issue), which planted the seeds for the concept of CHC cross-battery (CB) assessment; (b) the first attempt to use the WJ-R, via a Kaufman-like supplemental testing strategy (Kaufman, 1979), to implement the yet-to-be named and operationalized CHC CB approach to testing (McGrew, 1994); (c) the articulation of the first integrated CHC model and classification of the major intelligence batteries as per the CHC framework (McGrew, 1997); (d) the first description of the assumptions, foundations, and operational principles for CHC CB assessment and interpretation (Flanagan & McGrew, 1997; McGrew & Flanagan, 1998); (e) the publication of the first intelligence theory and assessment book to prominently feature CHC theory and assessment methods (*Contemporary Intellectual Assessment: Theories, Tests, and Issues*; Flanagan, Genshaft, & Harrison, 1997); (f) the publication of the CHC CB assessment series (Flanagan, Ortiz, & Alfonso, 2007; Flanagan, Ortiz, Alfonso, & Mascolo, 2006); (g) the completion of a series of CHC-organized studies that investigated the relations between CHC cognitive abilities and reading, math, and writing achievement (see McGrew & Wendling, this issue); (h) the articulation of CHC-grounded SLD assessment and eligibility frameworks (see Flanagan, Fiorello, & Ortiz, this issue); and (h) the subsequent CHC-grounded revisions or interpretations of a number of comprehensive individually administered intelligence test batteries (Differential Abilities Scales–II [DAS-II]; SB5; Kaufman Assessment Battery for Children, Second Edition [KABC-II]; WJ-III). The impact of CHC theory can also be seen in the recent revisions of the venerable Wechsler trilogy (Wechsler Preschool and Primary Scale of Intelligence [WPPSI-III]; Wechsler Intelligence Scale for Children, Fourth Edition [WISC-IV]; Wechsler Adult Intelligence Scales, Third Edition [WAIS-IV]; Kaufman, 2009).

The Promise of CHC Theory

Combine the past 20 years of CHC-driven intelligence test development and research activities with the ongoing refinement and extension of CHC theory (McGrew, 2005, 2009), and we conclude that these are exciting times in the field of intelligence research and intelligence test development. Is this excitement warranted in school psychology? Has the drawing of a reasonably circumscribed "holy grail" taxonomy of cognitive abilities led to the promised land of intelligence testing in the schools—using the results of cognitive assessments to better the education of children with special needs? Have we simply become more sophisticated in the range of measures and tools used to "sink shafts at more critical points" in the mind (see Lubinksi, 2000), which, although important for understanding and studying human individual differences, fails to improve diagnosis, classification, and instruction in education?

We believe that optimism is appropriate regarding the educational relevance of CHC-driven test development and research. Surprisingly, cautious optimism has been voiced by prominent school psychology critics of intelligence testing. In a review of the WJ-R, Ysseldyke (1990) described the WJ-R as representing "a significant milestone in the applied measurement of intellectual abilities" (p. 274). More importantly, Ysseldyke indicated that he was "excited about a number of possibilities for use of the WJ-R in empirical investigations of important issues in psychology, education, and, specifically, in special education. . . we may now be able to investigate the extent to which knowledge of pupil performance on the various factors is prescriptively predictive of relative success in school. That is, we may now begin to address treatment relevance" (p. 273). Reschly (1997), in response to the first CHC-based cognitive-achievement causal modeling research report (McGrew, Flanagan, Keith, & Vanderwood, 1997), which demonstrated that some specific CHC abilities are important in understanding reading and math achievement above and beyond the effect of general intelligence (*g*), concluded that "the arguments were fairly convincing regarding the need to reconsider the specific versus general abilities conclusions. Clearly, some specific abilities appear to have potential for improving individual diagnoses. Note, however, that it is *potential* that has been demonstrated" (Reschly, 1997, p. 238).

Clearly the promise of improved intelligence testing, vis-à-vis CHC organized test batteries, has been recognized since 1989. Has this promise been realized during the past 20 years? Has our measurement of CHC abilities improved? Has CHC-based cognitive assessment provided a better understanding of the relations between specific cognitive abilities and school achievement? Has it improved identification and classification? More importantly, in the current educational climate, where does CHC-grounded intelligence testing fit within the context of the emerging RTI paradigm?

Purpose and Description of Special Issue

The purpose of this special issue of *Psychology in the Schools* is to provide a forum for the presentation of research studies that have recently been conducted to examine CHC-based intelligence testing. In selecting articles for this special issue, we attempted to include those that would exemplify a range of research approaches and focus on different aspects of CHC-based intelligence testing. Thus, this issue includes two "taking stock" articles, three articles that examine the most recent revisions of CHC-based intelligence testing, as well as two articles that examine relationships between CHC factors and achievement and SLD identification.

This special issue begins with two articles that summarize the results of 20 years of factor analyses in the areas of intelligence testing and cognitive-achievement relations. In the first article, Keith and Reynolds (2010) present a summary of the factor analytic research on CHC theory and intelligence tests. Their results suggest that both theory-based and non–theory-based measures over the years are well explained by CHC theory. The second article, authored by McGrew and Wendling (2010), provides a synthesis of the existing research on CHC cognitive-achievement relations. A total of 19 studies were included, resulting in 134 total analyses overall. These analyses were divided among three age groups and four achievement domains, including basic reading skills, reading comprehension, basic math skills, and mathematical reasoning. The examination of this data resulted in a more distinct set of CHC cognitive-achievement relations than previously found. McGrew and Wendling conclude that these results support the use of intelligence testing in a flexible and referral-based manner within the emerging RTI model.

Following these summative articles, we included three research studies that examined current CHC-based measures of intelligence. Two articles focus on the DAS-II (Elliott, 2007). In the first of these, Keith, Low, Reynolds, Patel, and Ridley (2010) examined the internal factor structure of the DAS-II as it adheres to the CHC factor structure across individuals who ranged in age from 4 to 17 in the DAS-II standardization sample. Generally, their results indicate that the DAS-II adequately adhered to CHC factor structure across the age span examined. Thus, Keith and colleagues concluded that practitioners could consider the DAS-II a valid measure of the CHC broad factors, as well as *g*. In the second DAS-II–focused manuscript, Elliott, Hale, Fiorello, Dorvil, and Moldovan (2010) also used both standardization and clinical samples (poor readers and reading-specific learning disabilities) to assess the effects of the DAS-II (Elliott, 2007) broad CHC factors and the general factor (*g*) on the reading achievement as measured by the Wechsler Individual Achievement Test, Second Edition (WIAT-II; Psychological Corporation, 2001). Elliott and colleagues used structural equation modeling as well as communality analyses. Based on their results, the authors concluded that the predictive validity of the DAS-II is strongest when considering the CHC factors of the scale rather than the overall *g* factor.

Floyd, Bergeron, Hamilton, and Parra (2010) conducted a study that examined relationships among cognitive abilities as measured by the WJ-III Tests of Cognitive Abilities (WJ-III COG; Woodcock, McGrew, & Mather, 2001) and executive functions as measured by the Delis–Kaplan Executive Function System (DKEFS; Delis, Kaplan, & Kramer, 2001). Their study sample consisted of an independent general education sample of 100 children and adolescents. Floyd and colleagues conducted both an exploratory factor analysis (EFA) and a confirmatory factor analysis (CFA) on 25 tests of the WJ-III COG and the DKEFS. Results of these extensive analyses indicated that all 25 subtest scores measure a general construct, and 24 of the 25 subtests measure at least one of the five broad CHC theory factors.

In the last article in this special issue, Flanagan, Fiorello, and Ortiz (2010) examine a "third method" approach for the identification of SLDs within the RTI framework. The authors begin by reviewing previously proposed "third method" approaches, and then suggest a new, integrated "Hypothesis-Testing CHC Approach (HT-CHC)." Flanagan and colleagues assert that this method is better than RTI alone, and is a significant improvement over the ability–achievement discrepancy model.

It is our hope that the series of articles presented in this special issue will provide guidance to practicing school psychologists as to how to incorporate theory-driven assessment to best serve children at risk and those with potential exceptionalities. We also believe that the results presented in these seven articles will make a significant contribution to the research and scholarly literature in regard to CHC-based measures of intelligence. Thus, we hope that this special issue will stimulate continued interest and debate among researchers.

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