Revised/Updated Cattell-Horn-Carroll (CHC) Theory of Cognitive Ability Classifications of the WJ III Cognitive and Achievement Tests

Kevin S. McGrew, Ph.D.
Institute for Applied Psychometrics (IAP)

(www.iapsych.com & www.intelligencetesting.blogspot.com)

The revised/updated CHC classifications included in this document are based on the author's review of a variety of published and unpublished WJ III research (since the publication of the WJ III in 2001). A large portion of the reviewed analyses are unpublished multivariate exploratory analyses (exploratory/confirmatory factor analyses; cluster analyses; multidimensional scaling) of the WJ III norm data (by this author), some results which have been posted at www.iapsych.com or www.intelligencetesting.blogspot.com. These test classifications do not necessarily represent the position of other WJ III co-authors or the publisher of the WJ III (Riverside Publishing).

As outlined in previous writings (McGrew, 1997, 2005), most all of the broad CHC classifications are based on empirical research. Most all narrow ability classifications are based on expert consensus task analysis.

The current CHC test classifications should be considered more "relaxed" or "liberal" than prior published classifications. That is, all probable hypotheses, regardless of the number of times suggested in the research reviewed, if supported by theoretical and logical task analysis considerations, are included. The author has "erred" on the side of being more inclusive (liberal) in the range of narrow abilities measured by tests. This philosophy was embraced in the spirit of stimulating additional research and to guard against the *"premature hardening of WJ III CHC test categories."* Furthermore, these classifications *do not* reflect additional test interpretations that have been offered by this author (in presentations or via the internet) in the context of contemporary cognitive information processing/neuropsychological research and theory.

The reader is strongly encouraged to read McGrew (2005) for important background information that was used in the development of this document. A critical table and figure from McGrew (2005) are included at the end of this document.

McGrew, K. S. (2005). The Cattell-Horn-Carroll (CHC) theory of cognitive abilities: Past, present and future. In D. Flanagan, & Harrison (Eds.),*Contemporary intellectual assessment: Theories, tests, and issues* (p.136-202). New York: Guilford Press.

For on-line version of McGrew (2005) see http://www.iapsych.com/CHCPP/CHCPP.html

Broad CHC Domain/WJ III Cognitive (COG) & Achievement (ACH) tests	Hypothesized CHC Narrow Ability Classifications	Test Description
Short-term Memory (*Gsm*)		
Numbers Reversed (COG)	Working Memory (MW) Memory Span (MS) Temporal Tracking (***Ga***-UK)	Measures the ability to repeat a series of random numbers backward. The number sequences are presented by audio tape.
Memory for Words (COG)	Memory Span (MS)	Measures the ability to repeat lists of unrelated words in the correct sequence. The words are presented by audio tape.
Auditory Working Memory (COG)	Working Memory (MW) Memory Span (MS) Temporal Tracking (***Ga***-UK)	Measures the ability to retain two types of orally presented information and then repeat them in a specified order. The subject is presented a mixed series of words and digits and is asked to rearrange them by first saying the words in order and then the numbers. The task requires divided attention as the subject must perform two different mental operations simultaneously.
Memory for Sentences (COG)	Memory Span (MS) Listening Ability (***Gc***-LS)	Measures the ability to remember and repeat simple words, phrases, and sentences presented auditorily by a tape player.
Processing Speed (*Gs*)		
Visual Matching (COG)	Perceptual Speed: Scanning (Ps)	There are two different versions of this test. The Early Development (Edv) version is designed for use with preschool children and individuals who have developmental delays or reduced functioning. The task requires the person to point to the two mathcing shapes in a row of four to five shapes. This section has a 2-minute time limit and does not requre the subject to write. The second version is designed for individuals above the developmental level of an average 5-year-old. On this section, the subject is asked to locate and circle the two identical numbers in a row of sex numbers. This task proceeds in diffeculty from single-digit numbers to triple-digit numbers and has a 3-minute time limit.
Decision Speed (COG)	Speed of Reasoning (RE) Semantic Processing Speed (***Gt***-R4)	Measures the ability to rapidly scan a row of pictures and decide which of the two drawings are the most related. The decisions become slightly more abstract as the test progresses. The subject is instructed to complete as many rows of drawings as possible within a three-minute time limit.
Rapid Picture Naming (COG)	Naming Facility (NA)	Measures the ability to rapidly identify and orally name pictures of common objects. The stimulus pictures are presented in rows of five. The test has a two-minute time limit.
Pair Cancellation (COG)	Perceputal Speed:Complex (Pc) Sustained Attention (AC)	Measures the capacity for sustained attention (vigilance). The subject is presented with rows that contain repeating pictures of a dog and a ball (in no particular sequence) and must circle all instances of when the "ball is followed by the dog". The test has a three-minute time limit.
Cross Out (COG)	Perceptual Speed: Scanning (Ps)	Measures the ability to quickly scan and compare visual information. The subject must mark the five drawings in a row of 20 drawings that are identical to the first drawing in the row. The subject is given a 3-minute time limit to complete as many rows of items as possible.

Comprehension-Knowledge (*Gc*)		
Verbal Comprehension (COG)	Language Development (LD) Lexical Knowledge (VL)	Measures knowledge of word meanings and general language development. Test is comprised of four subtests. In Picture Vocabulary, the subject must name familiar and unfamiliar pictured objects. In Oral Vocabulary: Synonyms, the subject must say a word similar in meaning to the word presented. In Oral Vocabulary: Antonyms, the subject must say a word that is opposite in meaning to the word presented In Verbal Analogies the subject must complete phrases with words that indicate appropriate analogies.
General Information (COG)	General (verbal) Information (K0)	Measures knowledge of the common or typical characteristics of certain objects. The test has two subtest components: "what" and "where" questions. The questions are presented orally and the subject must state the answer to "where you would find...." and "what you would do with..." questions.
Story Recall (ACH)	Listening Ability (LS) Meaning. Memory (***Glr***-MM) Working Memory (***Gsm-***MW)	Measures the ability to recall increasingly complex stories presented orally to the subject. The subject is asked to tell back as much of the story as they can. The score is based on the number of correctly recalled story elements.
Story Recall-Delayed Recall (ACH)	Meaningful Memory (***Glr***-MM)	Measures the ability to recall (after 1 to 8 days) the stories presented in Oral Recall.
Understanding Directions (ACH)	Listening Ability (LS) Working Memory (***Gsm-***MW) Induction (***Gf***-RG)	Measures comprehension of linguistic concepts (receptive language). The subject is asked to follow oral directions by pointing to different items in a picture.
Picture Vocabulary (ACH)	Lexical Knowledge (VL)	Measures knowledge of word meanings. The subject must name familiar and unfamiliar pictured objects.
Oral Comprehension (ACH)	Listening Ability (LS)	Measures the ability to listen to a short tape-recorded passage and to verbally supply the single word missing at the end of the passage.
Academic Knowledge (ACH)	General (verbal) Information (K0) Information about Culture (K2) General Science Info (***Gkn***-K1) Geography Achievement (***Gkn***-A5)	Test is comprised of three subtests that collectively measure knowledge in various areas of the biological and physical sciences, history, geography, government, economics, art, music, and literature.
Long-term Retireval (*Glr*)		
Visual-Auditory Learning (COG)	Associative Memory (MA) Meaningful Memory (MM)	Measures the ability to associate new visual symbols (rebuses) with familiar words in oral language and to translate a series of symbols presented as a reading passage (a visual-auditory association task). This is a "learning" test where corrective feedback is provided to the subject.
Visual-Auditory Learning-Delayed Recall (COG)	Associative Memory (MA)	Measures the ability to recall and relearn (after 1 to 8 days) the symbols (rebuses) presented in Visual-Auditory Learning. This is a "relearning" task as the subject relearns forgotten associations. Corrective feedback is provided to the subject during the task.
Retrieval Fluency (COG)	Ideational Fluency (FI) Naming Facility (NA)	Measures fluency in retrieving the names of objects. The subject is asked to state as many items as they can of three different types, "things to eat or drink", "names of people", and "animals.
Memory for Names (COG)	Associative Memory (MA)	Measures the ability to learn associations between unfamiliar auditory and visual stimuli (an auditory—visual association task). The task requires learning the names of a series of space creatures. This is a "learning" test where corrective feedback is provided to the subject.

Memory for Names-Delayed Recall (COG)	Associative Memory (MA)	Measures the ability to recall (after 1 to 8 days) the space creatures presented in Memory for Names.
Visual-Spatial Processing (*Gv*)		
Spatial Relations (COG)	Spatial Relations (SR) Visualization (Vz)	Measures the ability to visually match and combine shapes. The subject must select from a series of shapes, the component parts composing a given whole shape.
Picture Recognition (COG)	Visual Memory (MV) Associative Memory (***Glr-***MA)	Measures the ability to recognize a subset of previously presented pictures within a larger set of pictures
Planning (COG)	Spatial Scanning (SS)	Measures the ability to plan a tracing route that covers as many segments of a dotted line drawing as possible without lifting the pencil or tracing over the same segment twice. The test requires "forward thinking" in that the subject is required to plan a sequence of steps prior to initializing the plan.
Visual Closure (COG)	Closure Speed (CS)	Measures the ability to name a drawing or picture of a simple object that is represented by disconnected lines. The test requires the subject to visually combine the disconnected lines into a meaningful whole.
Block Rotation (COG)	Visualization (Vz) Spatial Relations (SR)	Measures the ability to recognize two geometric designs (in a row of five) that are identical, although rotated to a different visual perspective from the target geometric design. Below the target stimulus are five pictures of geometric shapes or three-dimensional block strings that have been rotated in space. The subject must identify which two drawings are replications of the target item.
Auditory Processing (Ga)		
Sound Blending (COG)	Phonetic Coding (PC)	Measures the ability to perform auditory synthesis on segments of speech. After hearing the recorded parts (syllables and/or phonemes) of a word the subject must "blend" the parts together to make a whole word (synthesis task).
Incomplete Words (COG)	Phonetic Coding (PC)	Measures the ability to perform auditory closure on segments of speech. After hearing a recorded word with one or more phonemes missing, the subject must name the complete word (analysis task).
Auditory Attention (COG)	Speech Sound Discrimination (US) Attention/Concentration (AC)	Measures the ability to discriminate similar sounding words. An audio tape is used to present the words to the subject with increasing levels of background noise as a distracter.
Sound Patterns-Voice (COG)	General Sound Discrimination (U3)	Measures the ability to indicate whether pairs of complex sounds are the same or different. The sound patterns resemble human speech sounds. The pairs may differ in pitch, rhythm, or sound content.
Sound Patterns-Music (COG)	Musical Discrimination & Judgement (U1,U9)	Measures the ability to indicate whether pairs of musical sounds are the same or different. The pairs may differ in pitch, rhythm, or sound content.
Sound Awareness (ACH)	Phonetic Coding (PC) Working Memory (Gsm-MW)	Measures oral sound analysis skills at the preschool and primary level of development. It contains four subtests: Rhyming, Substitution, Deletion, and Reversal. The items are presented orally by the examiner, or by tape, and the subject responds orally.

Fluid Reasoning (*Gf*)		
Concept Formation (COG)	Induction (I)	Measures the ability to identify and state the rule for a concept about a set of colored geometric figures when shown instances and non-instances of the concept. This is a "learning" test with corrective feedback and reinforcement of correct answers provided to the subject.
Analysis-Synthesis (COG)	General Sequential (deductive) Reasoning (RG) Quantitative Reasoning (RQ)	Measures the ability to analyze the components of an incomplete logic puzzle and to determine and name the missing components. This is a "learning" test with corrective feedback and reinforcement of correct answers provided to the subject.
Number Series (COG)	Quantitative Reasoning (RQ)	Measures the ability to identify the quantitative principle that underlies a sequence of numbers in a series of numbers and then apply the principle to supply a missing number in the series.
Number Matrices (COG)	Quantitative Reasoning (RQ)	Measures the ability to identify the quantitative principle that underlies a series of numbers in matrices and then apply the principle to supply a missing number in the matrix.
Quantitative Knowledge (*Gq*)		
Calculation (ACH)	Math Achievement (A3)	Measures the ability to perform mathematical calculations ranging from simple addition to calculus. The subject is not required to make any decisions about what operations to use or what data to include.
Applied Problems (ACH)	Math Achievement (A3) Math Knowledge (KM) Quantitative Reasoning (***Gf***-RQ)	Measures the ability to analyze and solve problems in mathematics. The subject must decide not only the appropriate mathematical operations to use but also which of the data to include in the calculation.
Math Fluency (ACH)	Math Achievement (A3) Number Facility (***Gs***-N)	Measures the ability to quickly perform single-digit addition, subtraction, and multiplication facts. The subject is presented a series of simple arithmetic problems on a worksheet. The subject has two minutes to complete as many problems as possible.
Quantitative Concepts (ACH)	Math Knowledge (KM) Quantitative Reasoning (***Gf***-RQ) Lexical Knowledge (***Gc***-VL)	Measures the subject's mathematical vocabulary, concepts and quantitative reasoning. The test consists of two subtests that collectively represent a mixture of number series (Number Series(items and items requiring the subject to display mathematical knowledge (Concepts). The number series items require the subject to identify the underlying numerical relation in a series of numbers and then apply this principle by supplying a missing number in the series.
Reading and Writing (*Grw*)		
Letter-Word Identification (ACH)	Reading Decoding (RD) Lexical Knowledge (***Gc***-VL)	Measures the subject's reading skills in identifying isolated letters and words. It is not necessary that the subject knows the meaning of any words correctly identified.
Reading Fluency (ACH)	Reading Speed (RS) Semantic Processing Speed (***Gt***-R4)	Measures the ability to quickly comprehend the correctness of simple sentences. The subject is presented a series of simple sentences and must circle whether each sentence is true or false. The subject is required to complete as many items as possible within a 3-minute time limit.
Passage Comprehension (ACH)	Reading Comprehension (RC) Cloze Ability (CZ) Verbal (lang) Comprehension (V)	Measures the subject's skill in reading a short passage and identifying a missing keyword. In this modified cloze procedure, the subject must exercise a variety of comprehension and vocabulary skills.
Word Attack (ACH)	Reading Decoding (RC) Phonetic Coding (PC)	Measures the ability to apply phonic and structural analysis skills to the pronunciation of unfamiliar printed words. The subject reads aloud letter combinations that are linguistically logical in English but that do not form actual words (nonsense word), or words that constitute low-frequency words in

		the English language.

Reading Vocabulary (ACH)	Reading Comprehension (RC) Lexical Knowledge (***Gc***-VL)	Measures subject's skill in reading and understanding the meanings of words. The test consists of three subtests. In Part A: Synonyms, the subject must read a word and provide a word similar in meaning to the word presented. In Part B: Antonyms, the subject must read a word and provide a word that is opposite in meaning to the word presented. In Part C: Analogies, the subject must read an analogy and provide the missing word.
Spelling (ACH)	Spelling Ability (SG)	Measures the ability to write correct spellings of orally presented words.
Writing Fluency (ACH)	Writing Ability (WA) Speed of Writing (***Gps***-WS)	Measures the ability to formulate and write simple sentences quickly. This subtest has a 7-minute time limit.
Writing Samples (ACH)	Writing Ability (WA)	Measures the ability to write responses to a variety of demands. The subject must phrase and present written sentences that are evaluated with respect to the quality of expression. The subject is not penalized for errors in the basic mechanics of writing (spelling; punctuation).
Editing (ACH)	English Usage Knowledge (EU)	Measures the ability to identify, and indicate how to correct, mistakes in typewritten passages. The error in the passage may be incorrect punctuation or capitalization, inappropriate word usage, or a misspelling.
Spelling of Sounds (ACH)	Spelling Ability (SG) Phonetic Coding (***Ga***-PC)	Measures the ability to listen to a nonsense word and produce a written response representing the likely spelling of that word if it were a real English word. It is a measure of the subject's comprehension of the "alphabetic principle." The subject is presented the nonsense word from an audio tape and is asked to write it.
Punctuation and Capitalization (ACH)	English Usage Knowledge (EU)	Measures knowledge of punctuation and capitalization.

Broad (stratum II) and Narrow (stratum I) Cattell-Horn-Carroll (CHC) Ability Definitions

See following two sources for additional background literature and discussion of the contents of this table.

From McGrew, K. S. (2005). The Cattell-Horn-Carroll (CHC) theory of cognitive abilities: Past, present and future. In D. Flanagan, & Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (p.136-202). New York: Guilford Press.

On-line version also available at: http://www.iapsych.com/chcdef.htm. For on-line version of McGrew (2005) see http://www.iapsych.com/CHCPP/CHCPP.html

Fluid Intelligence/Reasoning (*Gf*): The use of deliberate and controlled mental operations to solve novel "on the spot" problems (i.e., tasks that cannot be performed automatically). Mental operations often include drawing inferences, concept formation, classification, generating and testing hypothesis, identifying relations, comprehending implications, problem solving, extrapolating, and transforming information. Inductive (inference of a generalized conclusion from particular instances) and deductive reasoning (the deriving of a conclusion by reasoning; specifically: inference in which the conclusion about particulars follows necessarily from general or universal premises) are generally considered the hallmark indicators of *Gf*. *Gf* has been linked to *cognitive complexity* which can be defined as a greater use of a wide and diverse array of elementary cognitive processes during performance.

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 solution to a problem. 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 undestanding of relatinships between events), conservation (awareness that physical quantitaties do not change in amount when altered in appearance), classification (abilty to organize materials that possess similar characteristics into categories), etc.

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*.

Crystallized Intelligence/Knowledge (*Gc*): "Can be thought of as the intelligence of the culture that is incorporated by individuals through a process of acculturation" (Horn, 1994, p.443). *Gc* is typically described as a person's wealth (breadth and depth) of acquired knowledge of the language, information and concepts of specific a 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.

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 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 an 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).
Communication Ability (CM): Ability to speak in "real life" situations (e.g., 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.
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). Not the skill in applying this knowledge.
Foreign Language Proficiency (KL): Similar to Language Development but for a foreign language.
Foreign Language Aptitude (LA): Rate and ease of learning a new language.

General (domain-specific) Knowledge (*Gkn*): An individual's breadth and depth of acquired knowledge in specialized (demarcated) domains that typically do no 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. The primary distinction between *Gc* and *Gkn* is the extent to which acquired knowledge is a function of the degree of cultural universality. *Gc* primarily reflects general knowledge accumulated via the experience of cultural universals.

Knowledge of English 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., ASL) used in communication with the deaf or hard of hearing.
Skill in Lip-reading (LP): Competence in 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. Since 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-Spatial Abilities (*Gv*): "The ability to generate, retain, retrieve, and transform well-structured visual images" (Lohman, 1994, p.1000). The *Gv* domain represents a collection of different abilities each that emphasize a different process involved in the generation, storage, retrieval and transformation (e.g., mentally reverse or rotate shapes in space) of visual images. *Gv* abilities are measured by tasks (figural or geometric stimuli) that require the perception and transformation of visual shapes, forms, or 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 primarily by a deemphasis on fluency.
Spatial Relations (SR): Ability to rapidly perceive and manipulate (mental rotation, tranformations, 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 (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).
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 (see chapter text).

Auditory Processing (*Ga*): Abilities that "depend on sound as input and on the functioning of our hearing apparatus" (Stankov, 1994, p. 157). A key characteristic of *Ga* abilities is the extent an individual can cognitively "control" (i.e., handle the competition between "signal" and "noise") the perception of auditory information (Gustafsson and Undheim, 1996), The *Ga* domain circumscribes a wide range of abilities involved in 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. Although *Ga* abilities play an important role in the development language abilities (*Gc*), *Ga* abilities do not require the comprehension of language (*Gc*).

Phonetic Coding (PC): Ability to code, process, and be sensitive to nuances in phonemic information (speech sounds) in short-term memory. 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 (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 (e.g., 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.

Short-term Memory (*Gsm*): The ability to apprehend and maintain awareness 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 short-term memory. 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 while the *visuo-spatial 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 chapter text) suggests that MW is *not* of the same nature as the other 60+ narrow factor-based trait-like 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 chapter text).

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. Horn (Horn & Masunaga, 2000) differentiates two major types of *Glr*--fluency of retrieval of information over minutes or a few hours (intermediate memory) and fluency of association in retrieval from storage over days, months or years. Ekstrom et al. (1979) distinguished two additional characteristic processes of *Glr*: "(1) reproductive processes, which are concerned with retrieving stored facts, and (2) reconstructive processes, which involve the generation of material based on stored rules" (p. 24). *Glr* abilities have been prominent in creativity research where they have been referred to as idea 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) where 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 given task requires the generation of numerous responses. 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, 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 individuals long-term memory store (i.e., objects or things to be named have names that are very familiar to the individual). In contemporary reading research is ability is called *rapid automatic naming* (RAN).

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 (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 non-meaningful 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 approaches to a given problem.

Sensitivity to Problems (SP): Ability to rapidly think of a number of alternative solutions to practical problems (e.g., different uses of a given tool). 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 where a standard operating procedure does not apply. Following a new and unique path to a solution. FO differs from FI in that FO focuses on the quality of creative responses while 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.

Cognitive Processing Speed (*Gs*): The ability to automatically and fluently perform relatively easy or over-learned cognitive tasks, especially when high mental efficiency (i.e., attention and focused concentration) is required. The speed of executing relatively over-learned or automatized elementary cognitive processes.

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 chapter text) suggests P may be an *intermediate* stratum ability (between narrow and broad) defined by four narrow sub-abilities: (1) *Pattern Recognition (Ppr)*--the ability to quickly recognize simple visual patterns; (2) *Scanning (Ps)*—ability to scan, compare, and look up visual stimuli; (3) *Memory (Pm)*--ability to perform visual perceptual speed tasks that place significant demands on immediate short-term memory, and (d) *Complex (Pc)*—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 which 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, 1998; Stankov, 2000). Recent research has suggested that R9 may better be classified as an *intermediate* (between narrow and broad strata) ability that subsumes most all psychometric speeded measures (see chapter text).

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 time. Also listed under *Gf*.

Reading Speed (fluency) (RS): Abiilty 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 copy correctly words or sentences repeatedly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under *Grw* and *Gps*.

Decision/Reaction Time or Speed (*Gt*): The ability to react and/or make decisions quickly in response to simple stimuli, typically measured by chronometric measures of reaction and inspection time. In psychometric methods, quickness in providing answers (correct or incorrect) to tasks of trivial difficult (CDS; correct decision speed)—may relate to cognitive tempo.

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 very briefly displayed stimulus (e.g., two different sized vertical lines joined horizontally across the top).

Psychomotor Speed (*Gps*): The ability to rapidly and fluently perform body motor movements (movement of fingers, hands, legs, etc.) 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): Ability to copy correctly words or sentences repeatedly, or writing 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.

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

Movement Time (MT): Recent research (see summaries by Deary, 2003; Nettelbeck, 2003; see chapter text) suggests 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 multi-limb movements or vocal articulation (diadochokinesis; Greek for "successive movements") (Carroll, 1993; Stankov, 2000) and is also listed under *Gt*.

Quantitative Knowledge (*Gq*): A person's wealth (breadth and depth) of acquired store of declarative and procedural quantitative knowledge. *Gq* is largely acquired through the "investment" of other abilities primarily during formal educational experiences. It is important to recognize that RQ, which is the ability to reason inductively and deductively when solving quantitative problems, is not included under *Gq*, but rather, is included in the *Gf* domain. *Gq* represents an individual's store of acquired mathematical knowledge, not reasoning with this knowledge.

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/Writing (*Grw*): A person's wealth (breadth and depth) of 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 sub-abilities (e.g., grapheme encoding, perceiving multi-letter units, and phonemic contrasts, etc.)

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

Verbal (printed) Language Comprehension (V): General development, or the understanding of words, sentences, and paragraphs in 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 only be supplied 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 (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): Abiilty 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 to copy words or sentences repeateadly, or writing words, sentences, or paragraphs, as quickly as possible. Also listed under *Gs* and *Gps*.

Psychomotor Abilities (*Gp*): The ability to perform body motor movements (movement of fingers, hands, legs, etc) with precision, coordination, or strength.

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 distirurbed.

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 (see chapter text)
Olfactory Memory (OM): Memory for odors (smells). Olfactory Sensitivity (OS): Sensitivity to different odors (smells).
Tactile Abilities (*Gh*): Abilities that depend on sensory receptors of the tactile (touch) system for input and on the functioning of the tactile apparatus. The cognitive and perceptual aspects of this domain have not yet been widely investigated (see chapter text)
Tactile Sensitivity (TS): The ability to detect and make fine discriminations of pressure on the surface of the skin.
Kinesthetic Abilities (*Gk*): Abilities that depend on sensory receptors that detect bodily position, weight, or movement of the muscles, tendons, and joints. 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). An ongoing effort to refine the CHC definitions of abilities can be found in the form of the *Cattell-Horn-Carroll (CHC) Definition Project* (http://www.iapsych.com/chcdef.htm).