Evolution of CHC Theory of Intelligence and Assessment

A. Early psychometric theory roots

- Galton and individual differences
- "Mental test" concept born
- Spearman-Holzinger g + model
- British Factor Analysis Tradition
- American Factor Analysis Tradition
- Gf-Gc theory
<table>
<thead>
<tr>
<th>Event Name</th>
<th>Start Date</th>
<th>End Date</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Early psychometric theory roots</td>
<td>1883</td>
<td>1979</td>
<td>Contemporary CHC theory can be traced to Spearman and early psychometrically-based theories</td>
</tr>
<tr>
<td>Galton and individual differences</td>
<td>1884</td>
<td>1890</td>
<td>Galton is generally considered to be the father of the field of individual differences via his interest in measuring, describing, and quantifying human differences and his interest in the genetics of geniuses. He establishes a large human individual differences &quot;anthroprometric&quot; lab.</td>
</tr>
<tr>
<td>&quot;Mental test&quot; concept born</td>
<td>1885</td>
<td>1890</td>
<td>The study of Individual differences in reaction time is credited with originating in German psychologist Wundt's lab. American student James McKeen Cattell is credited with coining the term &quot;mental test&quot; (Cattell, 1885, 1890) and starting this line of research. Wundt is reported to not have been interested in the study of individual differences.</td>
</tr>
<tr>
<td>Spearman-Holzinger g + model</td>
<td>1904</td>
<td>1939</td>
<td>Spearman developed a “two-factor theory” (general intelligence factor-g + specific factors's) to account for correlations between measures of sensory-discrimination (Galton tradition). Carroll (1993) suggested that it might be better called a &quot;one-general-factor theory.&quot; g was hypothesized to represent a fixed amount of “mental energy.” Spearman hypothesized that the g factor involved three major mental processes--apprehension of experience; eduction of relations; eduction of correlates. Spearman is generally credited with introducing the notion of factor analysis to the study of human abilities. According to Carroll (1983), Spearman and his students eventually began to study other possible factors beyond g. The Spearman-Holzinger Model (1993), which was based on Holzinger's development of the &quot;bi-factor&quot; method, suggested g plus five group factors (verbal, perceptual speed, spatial relations, recognition, and associative memory) (Spearman, 1939).</td>
</tr>
<tr>
<td>British Factor Analysis Tradition</td>
<td>1909</td>
<td>1961</td>
<td>The British models suggested that most of the variance of human intelligence was attributable to g and to very small group factors, and that the importance of the broader group factors was meager (Gustafsson, 1988). According to Gustafsson (1988), Burt’s model was to a great extent “logically constructed” and thus did not have major impact. In contrast, Horn stated that Burt’s model was very influential (Horn &amp; Noll, 1997). Vernon’s (1950, 1961) model, which had a g-factor at the apex of the hierarchy, and at the next level two major group-factors (verbal-numerical-educational-v:ed; spatial-practical-mechanical-physical--k:m) received more widespread attention.</td>
</tr>
</tbody>
</table>
American Factor Analysis Tradition 1928 1979

Primary use of multiple factor analysis methods [note: Carroll (1993) credits Garnett (1919) as being the originator of multiple factor analysis method] with the rotation of factors according to the “simple structure” criterion. This method does not readily identify a g-factor. The correlations among oblique factors typically factor analyzed in turn to produce “second-order” factors. Thurstone's first paper on multiple factor analysis was published in 1931 (Thurstone, 1931). Thurstone's theory posited 7-9 primary mental abilities (PMAs) that were independent of a higher-order g-factor. Although Thurstone is largely given credit for the multiple factors model, Carroll (1993) reports that Truman Kelley (1928) was the first US psychologist to report the findings of multiple factors (Kelly, 1928). Additionally, Carroll (1993) reports that Thurstone (1947) was willing to accept the possible existence of a g (general factor) above his primary mental abilities--and thus, suggests that Thurstone's model of human cognitive abilities was not fundamentally different from the Spearman--Holzinger g+group factors model. The primary difference, according to Carroll (1993), was differing viewpoints regarding the relative importance of the first-order primary mental abilities and the second-order g-factor. Although not all completed by Thurstone per se, during the 1940s-1960s many factor studies of human cognitive abilities were "conducted in the Thurstone tradition" (Carroll, 1993). This body of work was subsequently summarized by Ekstrom (1979). Summaries of the large body of PMA-based factor research suggested over 60 possible separate primary mental abilities (Ekstrom, French, & Harmon, 1979; French, 1951; French, Eckstrom, & Price, 1963; Guilford, 1967; Hakstian & Cattell, 1974; Horn, 1972). The ETS factor-reference group work established the WERCOF (well-replicated common factors) abilities. Most modern hierarchical theories of intelligence have their roots in Thurstone’s PMA theory (Horn & Noll, 1977). The formal beginning of the Cattell-Horn Gf-Gc theory. Fluid (Gf) and Crystallized (Gc) intelligence factors were extracted from second-order factor analysis of first-order (e.g., PMA) abilities.

Gf-Gc theory 1941 1965

Raymond Cattell was a student and research associate of Charles Spearman. He proposed the original Gf-Gc theory of intelligence (Cattell, 1941, 1943 ), the formal beginning of the Cattell-Horn Gf-Gc theory. Fluid (Gf) and Crystallized (Gc) intelligence factors were extracted from second-order factor analysis of first-order (e.g., PMA) abilities. Gf intelligence reflected basic reasoning abilities and higher mental processes while Gc reflected what an individual had learned from exposure to their culture through education and experiences, via the "investment" of their Gf abilities. According to Carroll (1993), it wasn't until John Horn, a student of Cattell's, completed his dissertation (Horn, 1965) that there was "the first clear test of the theory."
Research suggest more than two broad Gf-Gc ability domains

Horn, Cattell and others published systematic programs of research confirming the original Gf-Gc model and adding new broad Gv, Gs, Glr, Gsm and Ga factors [note - Horn et al. often used different terminology for broad factors such as Fluency for Glr, SAR for Gsm, etc.--contemporary CHC terms are used here]. Horn's (1976) review in the Annual Review of Psychology provides support for an expanded Gf-Gc model. Carroll & Maxwell's (1979) review in the Annual Review of Psychology, although not using classic Gf-Gc or contemporary CHC terms, suggests support for up to 9 different broad Gf-Gc abilities. Carroll & Maxwell discuss (a) Language Abilities and Skills [Gc, Grw], (b) Creativity and Fluency of Ideation [Glr], (c) Thinking, Reasoning and Problem Solving [Gf], (d) Abilities Concerned with Number and Quantity [Gq], (e) Perceptual Skills and Processes in Vision and Audition [Gv, Ga], (f) Memory Skills and Capacities [Gsm, Glr], and (g) Cognitive Speed [Gs]--[note--insertion of contemporary CHC broad ability abbreviations]
provided by this author--K. McGrew]. Support for the additional broad G-factors is based on the combination of structural (factor analytic), developmental, heritability, neurocognitive, and outcome-criterion evidence research. In 1994, Horn publishes probably his most succinct and understandable overview of extended Gf-Gc theory in "The Encyclopedia of Intelligence" (Sternberg, 1994).

### Carroll’s Model

<table>
<thead>
<tr>
<th>Year</th>
<th>1980</th>
<th>1993</th>
</tr>
</thead>
</table>

After over a decade of independent research, John "Jack" Carroll (1993) presents the most comprehensive empirically based synthesis of the extant factor analytic research (from prior 40+ years) regarding the structure of human cognitive abilities. A structure of intelligence was presented that included three hierarchical levels (strata) of abilities (narrow, broad, general) that differ by breadth of generality. The resulting summary provided a working taxonomy of human cognitive abilities by which to guide research and intelligence testing practice. Carroll's (1993) work is considered a seminal or classic work. More in-depth reviews and praise can be found in McGrew (2005) book chapter "CHC Theory: Past, Present and Future". After reviewing most all available models of human intelligence, Carroll (1993) concluded that the Cattell-Horn model was the model most similar to that established from his review of the extant factor analytic research. There were some differences between the Cattell-Horn and Carroll models, with the most salient point of disagreement being the inclusion (Carroll) or omission (Cattell-Horn) of a stratum-level general intelligence (g) ability at the apex of the structure of human cognitive abilities.

### "Unifying" Gf-Gc HILI model

<table>
<thead>
<tr>
<th>Year</th>
<th>1984</th>
<th>1988</th>
</tr>
</thead>
</table>

Gustaffson (1988) proposes and tests a three-level hierarchical LISREL model (HILI) model as a general unifying framework for integrating the British (Spearman, Burt, Vernon) and American (Thurston, Cattell, Horn) traditions of psychometric/theoretical research. According to Gustaffson, most all prior historical models (e.g., Cattell-Horn; Vernon) can be viewed as “classes” of models within the general HILI framework. Gf is suggested to be identical to g.

### Gq, Grw added

<table>
<thead>
<tr>
<th>Year</th>
<th>1985</th>
<th>1998</th>
</tr>
</thead>
</table>

In papers and book chapters spanning a number of years, John Horn had made consistent reference to an "English-language usage" factor. Similarly, the possibility of a broad "quantitative" ability had been mentioned as early as Carroll and Maxwell's (1979) synthesis in the Annual Review of Psychology. Armed with the large national norm data from the 1977 Woodcock-Johnson (WJ) and 1989 Woodcock-Johnson--Revised (WJ-R), Woodcock completed a number of CFA studies that solidified the validity of the broad Gq (Quantitative Knowledge or Ability) and Reading/Writing (Grw) ability domains.
Evolution of CHC Theory of Intelligence and Assessment

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Gf-Gc based IQ battery published (WJ-R)</td>
<td>1989</td>
<td>1991</td>
</tr>
<tr>
<td>Gf-Gc/CHC &quot;cross-battery&quot; assessment born</td>
<td>1990</td>
<td>1994</td>
</tr>
</tbody>
</table>

Extended Gf-Gc theory impacts applied IQ test development. The "first generation" Gf-Gc assessment approaches focused almost exclusively on the broad (stratum II) level.


Woodcock's (1990) Gf-Gc based confirmatory factor analysis (CFA) of multiple “cross-battery” data sets produces the concept of cross-battery (CB) assessment and interpretation, as well as supporting the construct validity evidence for WJ-R and Gf-Gc theory. Individual tests from the major intelligence batteries (DAS, DTLA-3, KABC, SB-IV, WJ/WJ-R, WISC-R/WAIS/WAIS-R) were classified at the broad (stratum II) Gf-Gc ability level via a series of joint/CB CFA studies. McGrew (1994) presented the first "informal/clinical" approach to Gf-Gc cross-battery assessment for supplementing WJ-R assessments...still focused at the
**Evolution of CHC Theory of Intelligence and Assessment**

<table>
<thead>
<tr>
<th>Event</th>
<th>Year 1</th>
<th>Year 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>KAIT Gf-Gc battery published</td>
<td>1993</td>
<td></td>
</tr>
<tr>
<td>First edition CIA book published</td>
<td>1997</td>
<td></td>
</tr>
</tbody>
</table>
conducting Gf-Gc cross-battery assessments. A major outcome of two chapters in the book (Flanagan & McGrew, 1997; McGrew, 1997) was the realization that "First generation Gf-Gc assessments" had been neglecting the importance of "adequate construct representation" via the inclusion of 2 or more narrow (stratum I) abilities in test battery composites intended to represent a broad Gf-Gc stratum II ability. Finally, McGrew (1997) presents the first "official" Gf-Gc broad/narrow ability definitions extracted from Carroll (1993). Carroll reviewed and approved the final set of definitions provided by McGrew after a number of McGrew iterations based on Carroll feedback. See McGrew (2005) for more detailed discussion of the CIA book.

| Carroll-Horn-Carroll (CHC) umbrella term agreement | 1998 | 1999 |

The derivation of the name "Cattell-Horn-Carroll" (CHC) theory remains a mystery to many. McGrew (2005) describes the unique set of circumstances that resulted in Carroll and Horn agreeing to the use of the umbrella title "Cattell-Horn-Carroll (CHC) Theory of Cognitive Abilities" (circa 1999). Having dealt communication problems via the use of Gf-Gc theory labels since the WJ-R was published in 1989, Richard Woodcock, together with the Stanford Binet Intelligence Scales—Fifth Edition (SB5; Roid, 2003) author, and staff from Riverside Publishing, brokered a private meeting with Horn and Carroll in Chapel Hill, NC, to seek a common, more meaningful, umbrella term that would recognize the strong structural similarities of their respective theoretical models, yet also recognize their differences. Woodcock engaged Horn and Carroll in a sequence of conversations that resulted in a verbal agreement that the phrase “Cattell-Horn-Carroll Theory of Cognitive Abilities” made significant practical sense, and, appropriately recognized the historical order of scholarly contribution of the three primary contributors). “CHC” emerged from private personal communications in July, 1999, and seeped into subsequent publications.
The unified CHC model impacts applied IQ test development. The "second generation" CHC assessment approaches now focus on adequate broad ability construct representation in composite scores via the inclusion of multiple narrow CHC abilities.

McGrew (1997) recognizes the importance of narrow ability construct representation when evaluating the validity of broad CHC composite scores. Flanagan & McGrew (1998) present first empirical study (joing WJ-R/KAIT) that recognizes the importance of both broad and narrow abilities in construct valid broad measures. The need to consider both the broad and narrow abilities in cross-battery CFA model specification and interpretation is presented.

McGrew & Flanagan (1998), in the "Intelligence Test Desk Reference (ITDR)", present a comprehensive description and formal operationalization of how the Gf-Gc cross-battery assessment approach can be applied to all major intelligence batteries (and select special purpose tests). The first Wechsler-specific CHC cross-
Evolution of CHC Theory of Intelligence and Assessment

battery approach is later presented (Flanagan, McGrew & Ortiz (2001), followed by additional refinements to CB approach (Flanagan, Ortiz, Alfonso & Mascolo, 2002). Additional special purpose cognitive tests and tests from major individually administered achievement batteries classified as per CHC theory. The first operational LD model based on CHC theory is presented in the Achievement Test Desk Reference (Flanagan et al., 2002).

The WJ III (Woodcock, McGrew & Mather, 2001), a revision of the 1989 WJ-R, is the first individually administered IQ (and achievement) battery designed as per CHC theory. The over-arching design goal was to insure adequate construct representation (and minimization of construct irrelevant variance) of 9 broad CHC abilities. Each broad CHC ability cluster is represented by two or more qualitatively different narrow ability test indicators. John Horn and and Jack Carroll served as consultants to WJ III revision team.

Other major IQ tests are revised and place the CHC model as the central focus of each batteries design blueprint. SB5 (Roid, 2003) revision includes composite scores for 5 broad abilities (Gf, Gc, Gq, Gsm, Gv), via verbal and nonverbal tests. Horn, Cattell, Woodcock and McGrew serve as consultants to SB5 revision team. Kaufman & Kaufman (2004) revise the KABC-II with a dual theoretical model blueprint, but with the CHC model recommended as the primary organizational structure to use. Elliott (2007) revises the Differential Abilities Scales--II (DAS-II) with a heavy CHC influence.

At 2008 Neuropsychology conference Richard Woodcock summarizes, with the aid of an important visual-graphic, the historical evolution of IQ tests.
F. CHC model evaluation and extensions

1996 2009 The CHC model is further validated and research suggests both internal and external extensions.

- Research suggests additional broad CHC domains
- Research suggests hierarchical speed taxonomy
- Human Cognitive Abilities (HCA) project
- CHC "state-of-the-art" synthesis (McGrew, 2005, 2009)
- Research supports broad CHC model
- CHC broad and narrow ability "working" definitions

Research suggests additional broad CHC 1997 2005 McGrew's (2005) review of contemporary research finds evidence for research and scholars who suggest the
<table>
<thead>
<tr>
<th>Domains</th>
</tr>
</thead>
<tbody>
<tr>
<td>addition of a number of broad abilities to the CHC taxonomy. These include olfactory abilities (Go), general domain-specific knowledge (Gkn), psychomotor speed (Gps), psychomotor abilities (Gp), tactile abilities (Gh), and kinesthetic abilities (Gk). See McGrew (2005) and McGrew &amp; Evans (2004) for detailed summary.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Research suggests hierarchical speed taxonomy</th>
<th>1999</th>
<th>2002</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Human Cognitive Abilities (HCA) project</th>
<th>2002</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Woodcock-Muñoz Foundation Human Cognitive Abilities Project (HCA) is continuing program of research using the original data sets associated with Carroll's (1993) work. These activities include: (a) electronic archiving of the correlation matrices and associated publications from Carroll’s collection, and (b) the development of mechanisms for electronically storing and disseminating portions of the HCA collection to independent researchers. The WMF HCA project seeks to build upon the past 60+ years of factor analytic research regarding the structure of human cognitive abilities. The primary goals of the HCA project are to (a) refine and extend the understanding of the nature of the structure of human cognitive abilities, (b) electronically archive, document, and make accessible (to students and researchers) the 460 plus data sets used in Carroll's factor analytic review, and (c) facilitate the development and implementation of plans for a retrospective re-analysis of the data sets analyzed by Carroll with contemporary statistical methods (e.g., confirmatory factor analysis). See McGrew (2009) for detailed description of CHC theory and the HCA project. The HCA project was originally started by the Institute for Applied Psychometrics (IAP; Kevin McGrew) in 2002.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

|----------------------------------------------------------|------|------|

<table>
<thead>
<tr>
<th>Research supports broad CHC model</th>
<th>2005</th>
<th>2009</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>CHC broad and narrow ability &quot;working&quot; definitions</th>
<th>2009</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>McGrew's (1997) original broad and narrow CHC ability definitions are revised in the form of a &quot;working&quot; document, subject to ongoing revision.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Spearman's general factor model

(T# = designates different test measures)
Thurston's Multiple Factor (Primary Mental Abilities) Model

(T# = designates different test measures)
(PMA# = different “primary mental ability”)
Cattell Dichotomous Gf-Gc (no g) Model

(T# = designates different test measures)
(PMA# = different "primary mental ability")
Cattell-Horn Gf-Gc Hierarchical (no g) Model

(T# = designates different test measures)
(PMA# = different "primary mental ability")
Carroll’s Schmid-Leiman Hierarchical Three-Stratum Model

(T# = designates different test measures)
(PMA# = different “primary mental ability”)
Carroll and Cattell-Horn Model Comparison

- **Carroll**
  - Gf: Fluid Intelligence
  - Gc: Crystallized Intelligence
  - Gy: Gen. Memory & Learning
  - Gv: Broad Visual Perception
  - Gu: Broad Auditory Perception
  - Gr: Broad Retrieval Ability
  - Gs: Broad Cognitive Speediness
  - Gt: Dec./Reaction Time/Speed

- **Cattell-Horn**
  - Gf: Fluid Intelligence
  - Gg: Quantitative Knowledge
  - Gh: Crystallized Intelligence
  - Gvm: Short-Term Memory
  - Gv: Visual Processing
  - Gv: Auditory Processing
  - Gv: Long-Term Retrieval
  - GPs: Processing Speed
  - Gr: Correct/Reaction Time
  - Gw: Reading/Writing
Evolution of CHC Theory of Intelligence and Assessment

Consensus Cattell-Horn-Carroll Hierarchical Three-Stratum Model

(T# = designates different test measures)
(PMA# = different "primary mental ability")
Figure 1: Major stages in the evolution of psychometric theories from Spearman's g to Carrell-Horn-Carroll (CHC) theory.
A. Carroll Three-Stratum Model

B. Cattell-Horn Extended GF-Gc Model

C. Cattell-Horn-Carroll (CHC) Integrated Model

D. Tentatively identified Stratum II (broad) domains

CHC Broad (Stratum II) Ability Domains

- Gf: Fluid reasoning
- Gc: Comprehension-knowledge
- Gy: Short-term memory
- Gv: Visual processing
- Ga: Auditory processing
- Gr: Long-term storage and retrieval
- Gs: Cognitive processing speed
- Gt: Decision and reaction speed
- Gnw: Reading and writing
- Gq: Quantitative knowledge
- Gkn: General (domain-specific) knowledge
- Gh: Tactile abilities
- Gk: Kinesthetic abilities
- Go: Olfactory abilities
- Gp: Psychomotor abilities
- Gps: Psychomotor speed

80+ Stratum I (narrow) abilities have been identified under the Stratum II broad abilities. They are not listed here due to space limitations (see Table 1)

Carroll and Cattell-Horn Broad Ability Correspondence (vertically-aligned ovals represent similar broad domains)

Stratum III (general)

Stratum II (broad)