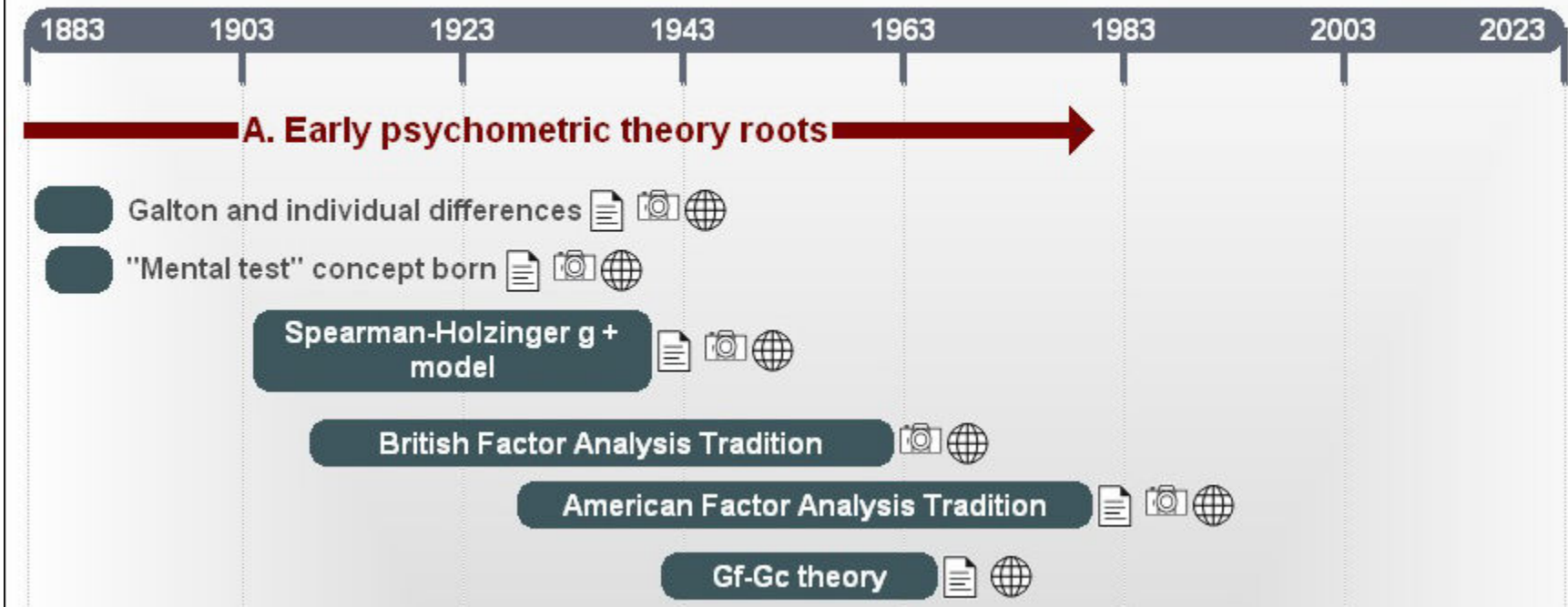


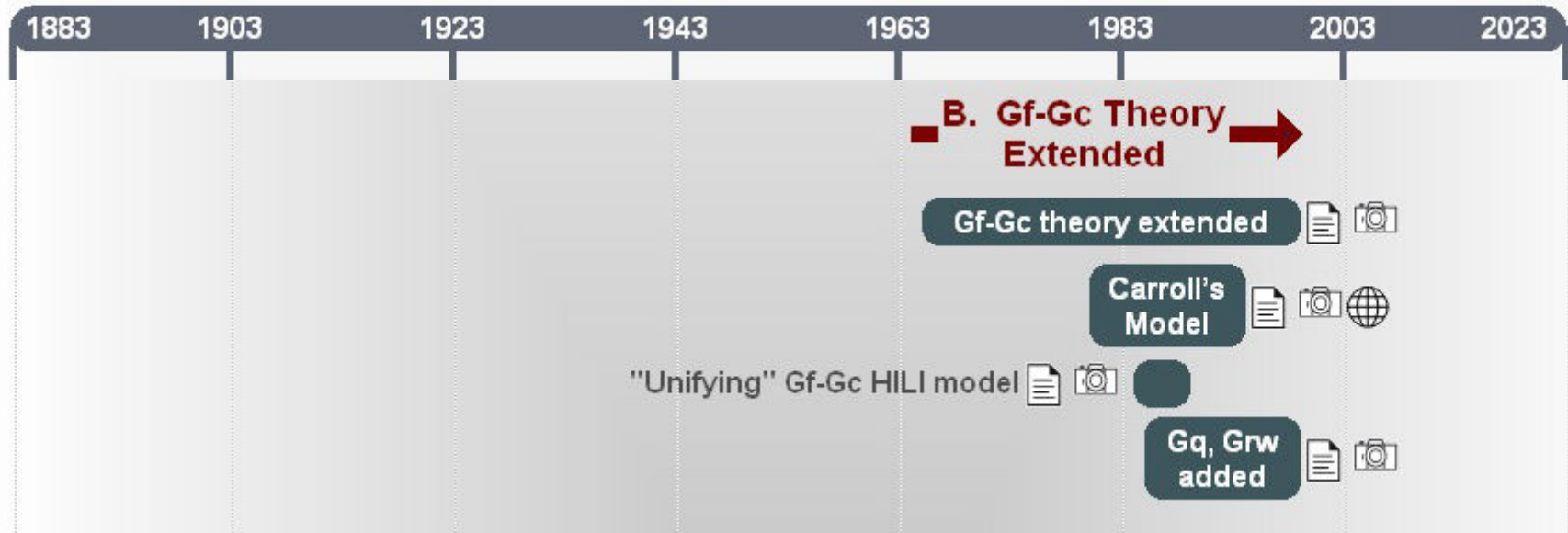
Evolution of CHC Theory of Intelligence and Assessment



Event Name	Start Date	End Date	Notes
A. Early psychometric theory roots	1883	1979	Contemporary CHC theory can be traced to Spearman and early psychometrically-based theories
Galton and individual differences	1884	1890	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 "anthropometric" lab.
"Mental test" concept born	1885	1890	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 "mental test" (Cattell, 1885, 1890) and starting this line of research. Wundt is reported to not have been interested in the study of individual differences.
Spearman-Holzinger g + model	1904	1939	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 "one-general-factor theory." 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; education of relations; education 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 "bi-factor" method, suggested g plus five group factors (verbal, perceptual speed, spatial relations, recognition, and associative memory) (Spearman, 1939).
British Factor Analysis Tradition	1909	1961	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 & 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.

American Factor Analysis Tradition	1928	1979	<p>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.</p>
Gf-Gc theory	1941	1965	<p>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."</p>

Evolution of CHC Theory of Intelligence and Assessment



B. Gf-Gc Theory Extended

1964

1998

Research suggest more than two broad Gf-Gc ability domains

Gf-Gc theory extended

1965

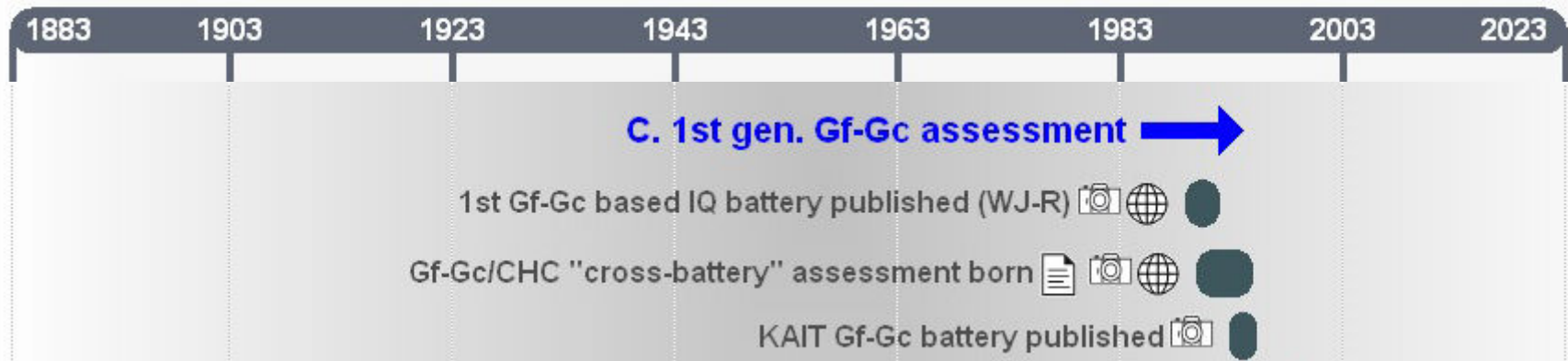
1998

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	1980	1993	<p>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.</p>
"Unifying" Gf-Gc HILI model	1984	1988	<p>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.</p>
Gq, Grw added	1985	1998	<p>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.</p>

Evolution of CHC Theory of Intelligence and Assessment



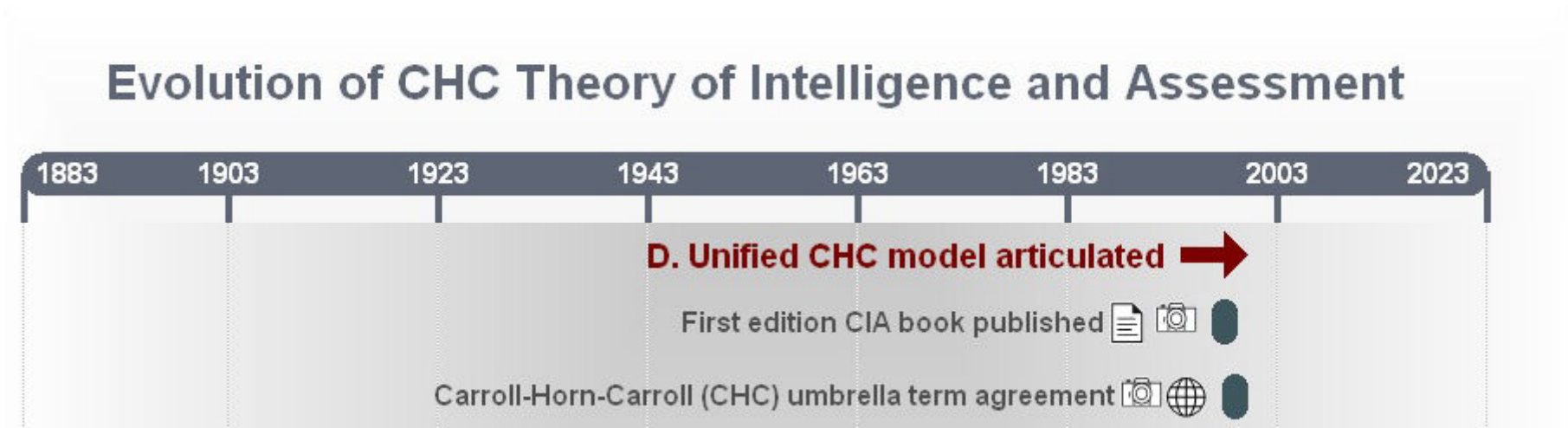
C. 1st gen. Gf-Gc assessment	1985	1993	Extended Gf-Gc theory impacts applied IQ test development. The "first generation" Gf-Gc assessment approaches focused almost exclusively on the broad (stratum II) level.
1st Gf-Gc based IQ battery published (WJ-R)	1989	1991	The Horn-Carroll-Woodcock "fortuitous" tripartite. Horn and Cattell served as consultants to WJ-R revision team resulting in the first major Gf-Gc theory-to-practice "bridging" or cross-fertilization event that impacted the applied measurement of intelligence. Horn, Carroll, Woodcock, and McGrew independently factor analyzed 1977 WJ battery as per CHC (Gf-Gc) theory and the integrated results formed the basis for the WJ-R test specification design blueprint. (1986-1987). The WJ-R represented the first individually administered battery designed as per Cattell-Horn Gf-Gc theory to measure 9 broad abilities. Horn published an overview of Gf-Gc theory in a special appendix in the WJ-R Technical Manual (McGrew & Woodcock, 1991). See McGrew (2005) for more details.
Gf-Gc/CHC "cross-battery" assessment born	1990	1994	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

broad/stratum II ability level.

KAIT Gf-Gc battery published

1993

Dichotomous (Gf-Gc) Cattell based Kaufman Adolescent and Adult Intelligence (KAIT) battery published (Kaufman & Kaufman, 1993). Flanagan & McGrew (1998) later provide clarification of the breadth of Gf-Gc/CHC broad and narrow abilities measured by the individual KAIT tests.



D. Unified CHC model articulated

1994

1999

Cattell-Horn Gf-Gc and Carroll Three-Stratum models integrated under a single umbrella framework.

First edition CIA book published

1997

The first intelligence assessment and theory book to include multiple chapters reflecting the bridging of Gf-Gc theory (e.g., Horn and Carroll chapters) and applied assessment and interpretation. The collective influence of Cattell-Horn, Gf-Gc theory, and Carroll's research was reflected in nine chapters devoted to, or including significant treatment of, Gf-Gc theory and testing. All tests from major intelligence batteries were logically classified at both the broad and narrow ability levels as per the first proposed "Synthesized/Integrated Cattell-Horn and Carroll Gf-Gc Model" (McGrew, 1997), the predecessor of the formal Cattell-Horn-Carroll (CHC) theory. The lack of CFA cross-battery studies that specified both broad and narrow Gf-Gc factors led to expert-consensus content validity Gf-Gc narrow ability test classifications. Flanagan and McGrew introduced the "Three Pillars of Cross-Battery Assessment" (theory, construct relevant variance, construct representation) and provide the first general operational framework for

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.

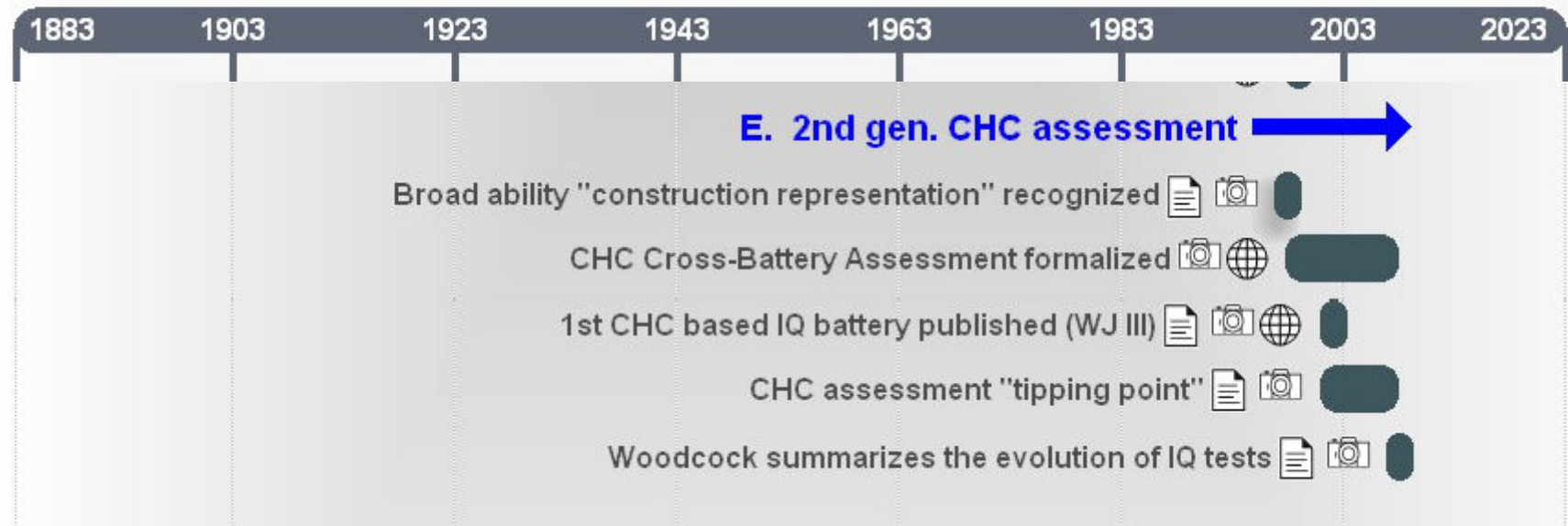
Carroll-Horn-Carroll (CHC) umbrella term agreement

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.

Evolution of CHC Theory of Intelligence and Assessment

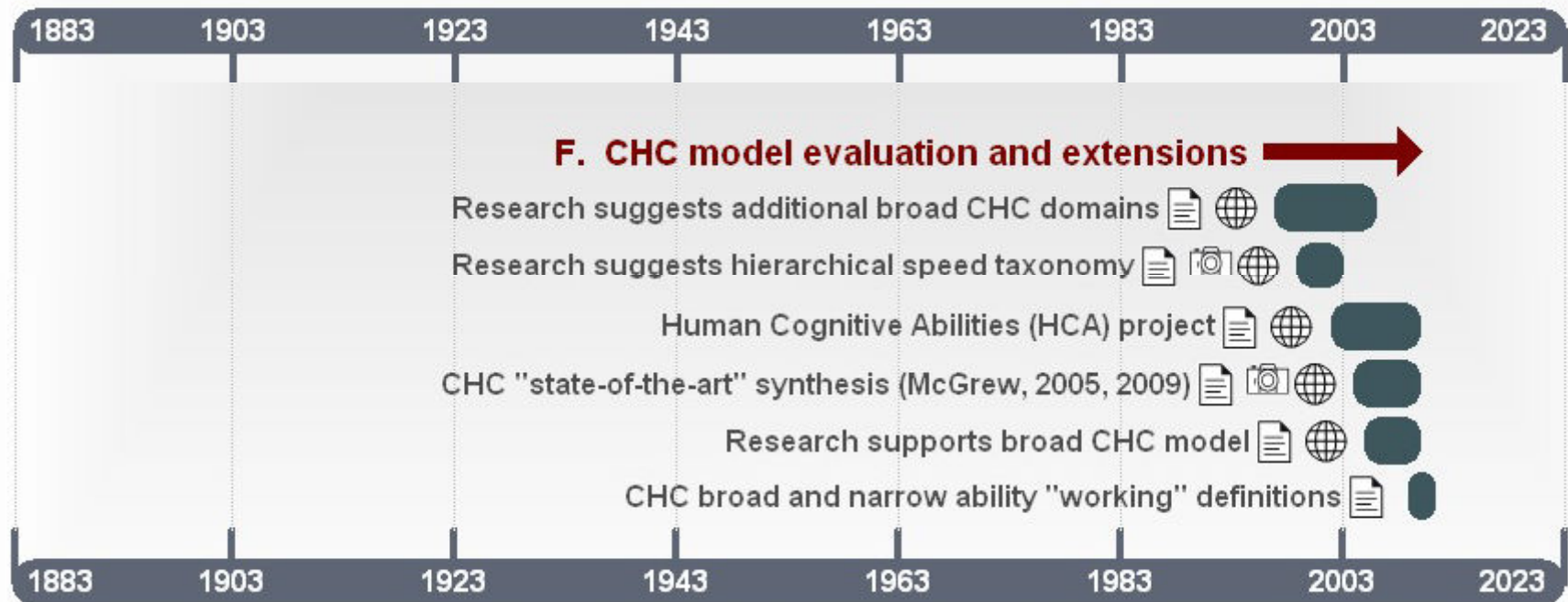


E. 2nd gen. CHC assessment	1995	2008	The unified CHC model impacts applied IQ test development. The "second generation" CHC assessment approaches now focus on adequate broad ability construct representation in composite scores via the inclusion of multiple narrow CHC abilities.
Broad ability "construction representation" recognized	1997	1998	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 (joining 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.
CHC Cross-Battery Assessment formalized	1998	2007	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-

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).

1st CHC based IQ battery published (WJ III)	2001	2001	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 Jack Carroll served as consultants to WJ III revision team.
CHC assessment "tipping point"	2001	2007	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.
Woodcock summarizes the evolution of IQ tests	2007	2008	At 2008 Neuropsychology conference Richard Woodcock summarizes, with the aid of an important visual-graphic, the historical evolution of IQ tests.

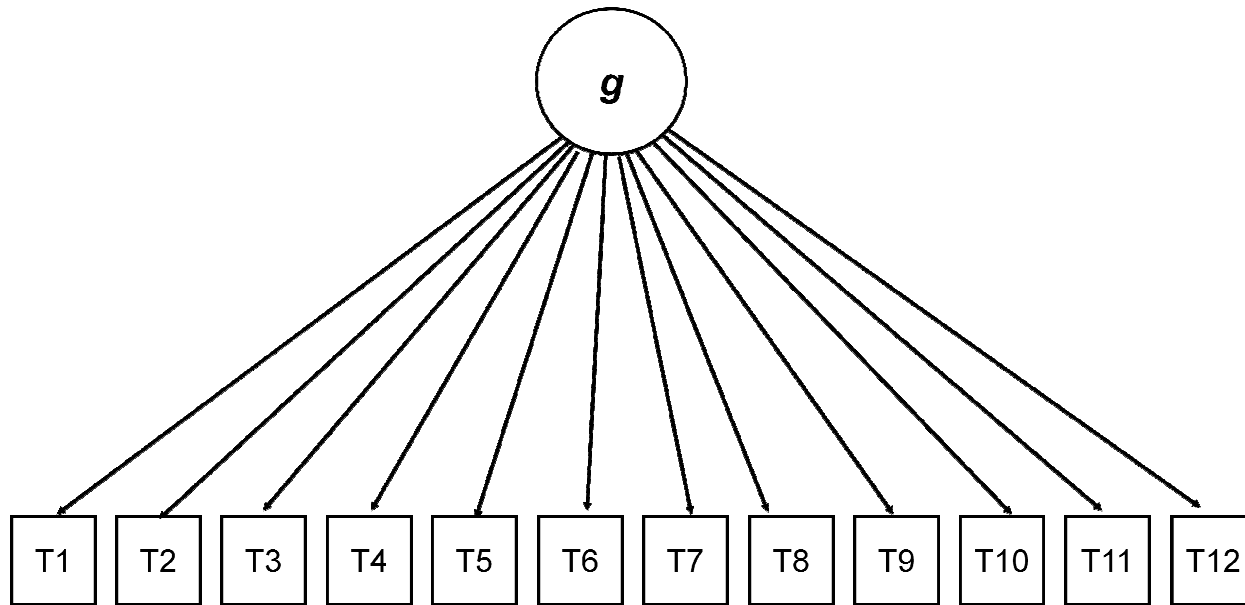
Evolution of CHC Theory of Intelligence and Assessment



F. CHC model evaluation and extensions

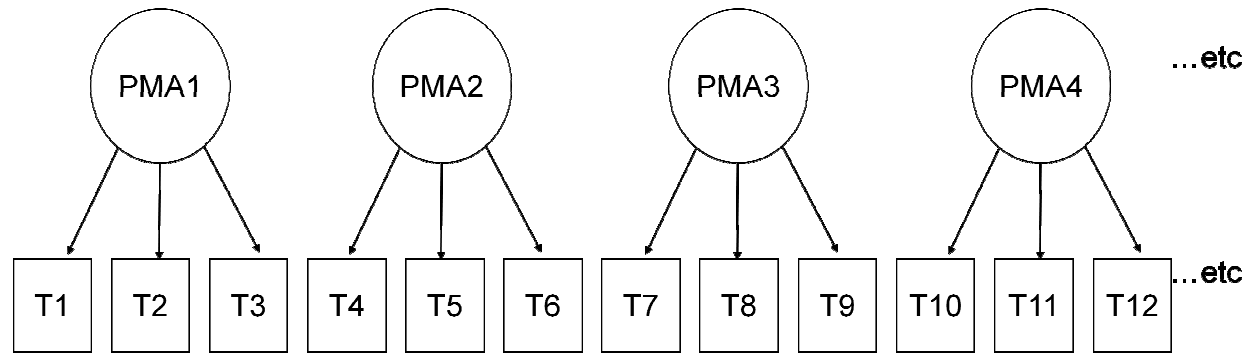
	1996	2009	The CHC model is further validated and research suggests both internal and external extensions.
Research suggests additional broad CHC	1997	2005	McGrew's (2005) review of contemporary research finds evidence for research and scholars who suggest the

domains			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 & Evans (2004) for detailed summary.
Research suggests hierarchical speed taxonomy	1999	2002	McGrew's (2005) review of contemporary factor analysis research results in the presentation of a hypothesized hierarchical speed taxonomy, See McGrew (2005) and McGrew & Evans (2004) for details.
Human Cognitive Abilities (HCA) project	2002	2009	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.
CHC "state-of-the-art" synthesis (McGrew, 2005, 2009)	2004	2009	McGrew provides the most recent 'state-of-the-art' summaries of CHC theory (including historical background) in book chapter (McGrew, 2005) in Flanagan & Harrison (2005) 2nd Edition of "Contemporary Intellectual Assessment" and an invited editorial in the journal Intelligence (McGrew, 2009). See McGrew (2005, 2009) for more detail.
Research supports broad CHC model	2005	2009	McGrew's (2005) review of contemporary factor analysis studies provides support for the broad strokes of CHC theory--Gf, Gv, Gsm, Glr, Gs, Gq, and Grw. See McGrew (2005) and McGrew and Evans (2004) a for detailed summary.
CHC broad and narrow ability "working" definitions	2009	2009	McGrew's (1997) original broad and narrow CHC ability definitions are revised in the form of a "working" document, subject to ongoing revision.



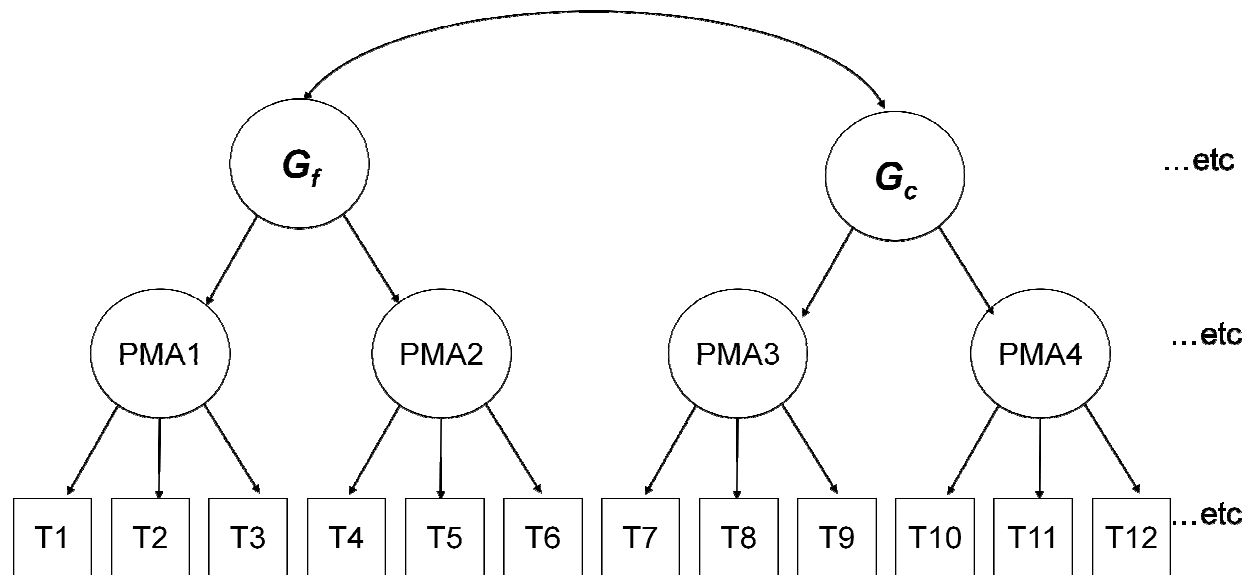
Spearman's general factor model

(T# = designates different test measures)



Thurston's Multiple Factor (Primary Mental Abilities) Model

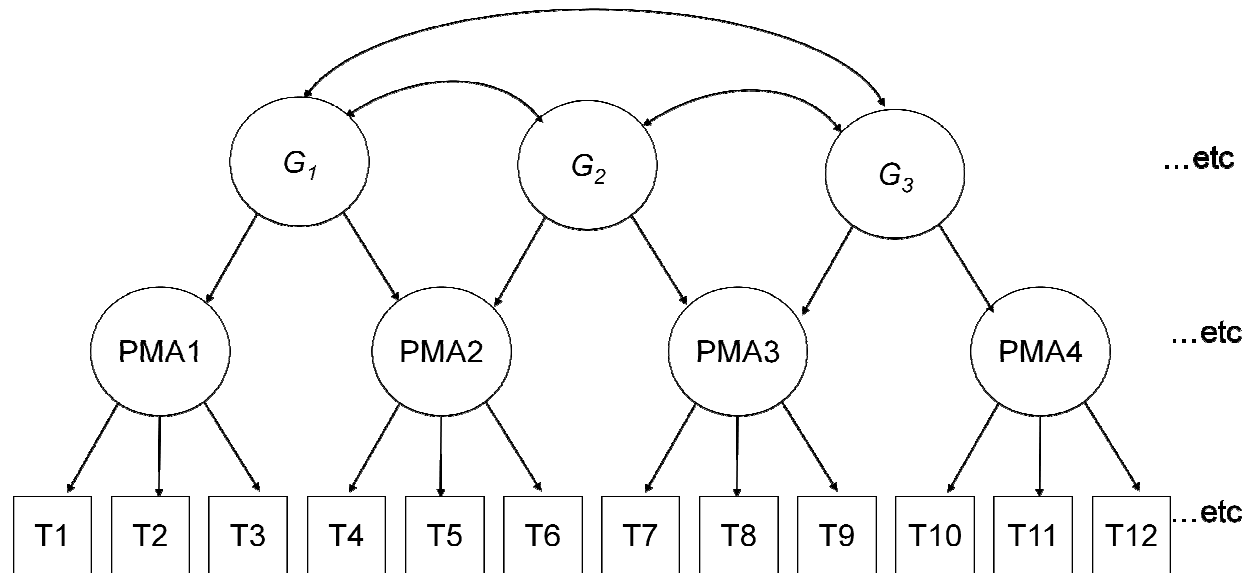
(T# = designates different test measures)
(PMA# = different "primary mental ability")



Cattell Dichotomous Gf-Gc (no g) Model

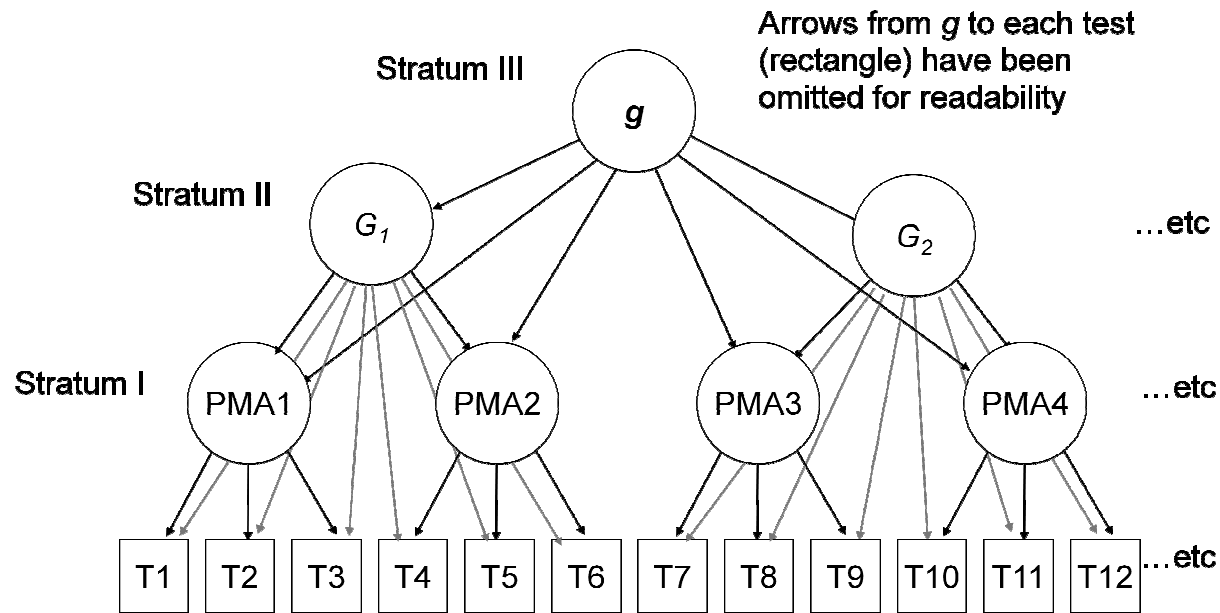
(T# = designates different test measures)

(PMA# = different “primary mental ability”)



Cattell-Horn *Gf-Gc* Hierarchical (no *g*) Model

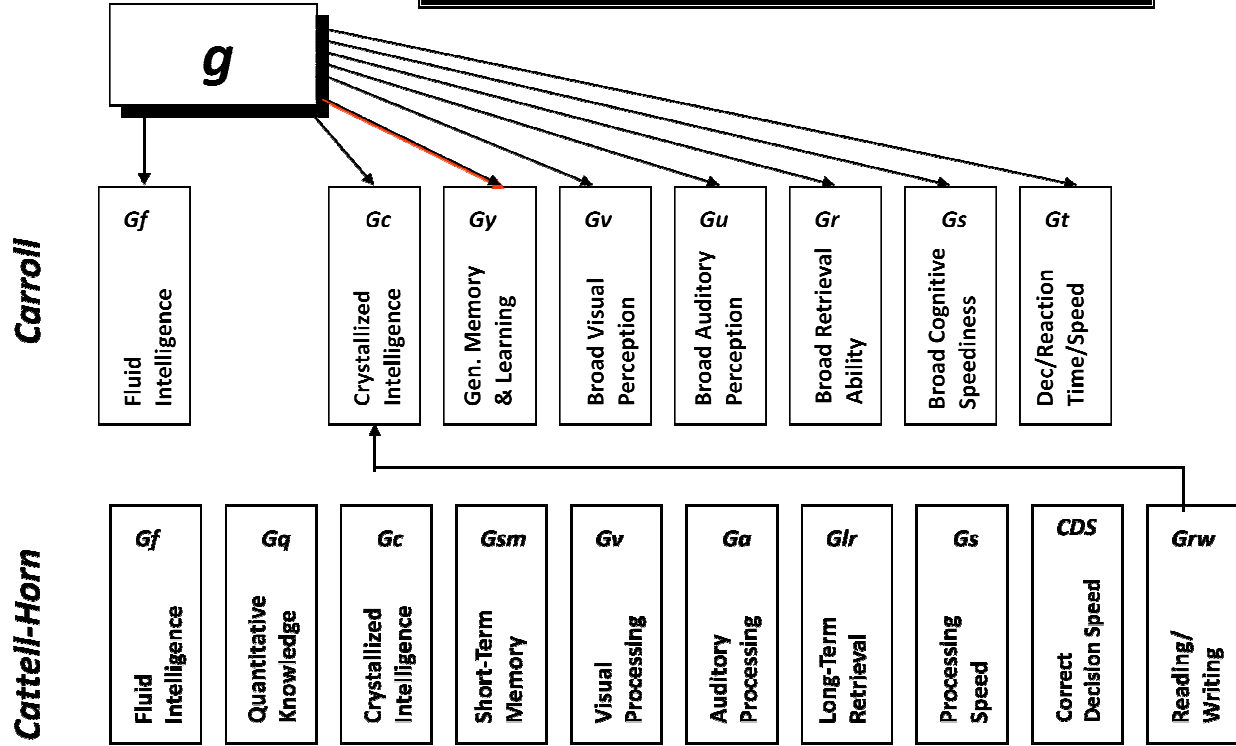
(T# = designates different test measures)
 (PMA# = different “primary mental ability”)

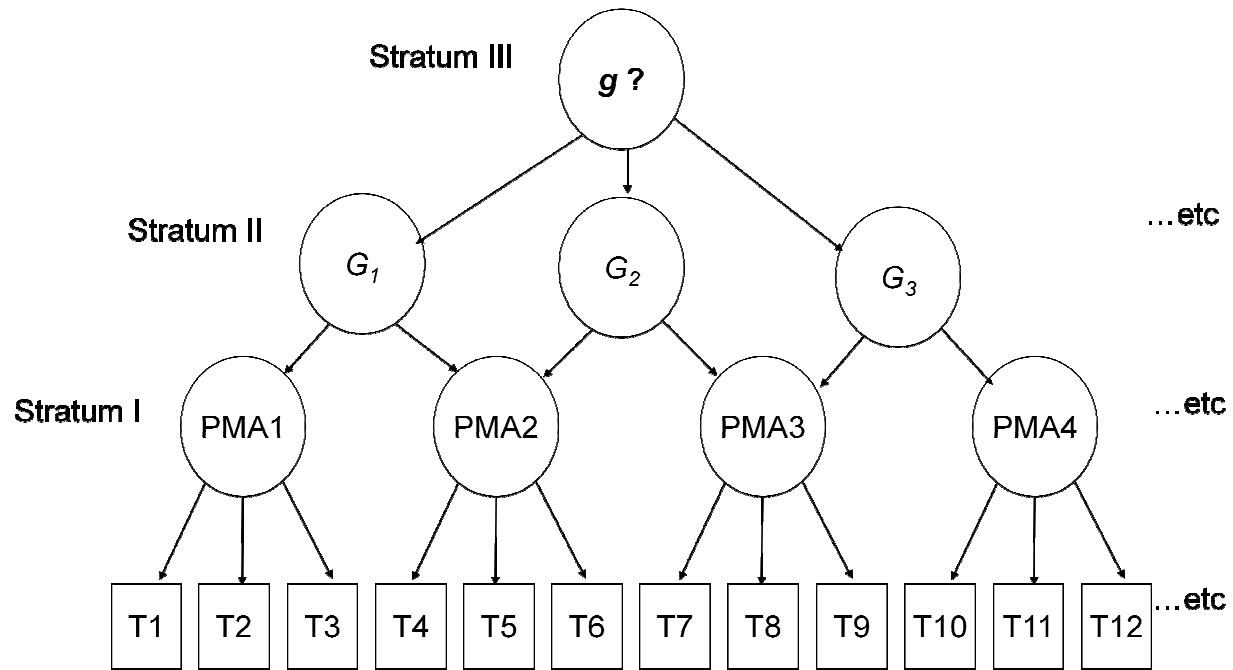


Carroll's Schmid-Leiman Hierarchical Three-Stratum Model

(T# = designates different test measures)
 (PMA# = different "primary mental ability")

Carroll and Cattell-Horn Model Comparison





Consensus Cattell-Horn-Carroll Hierarchical Three-Stratum Model

(T# = designates different test measures)
 (PMA# = different "primary mental ability")

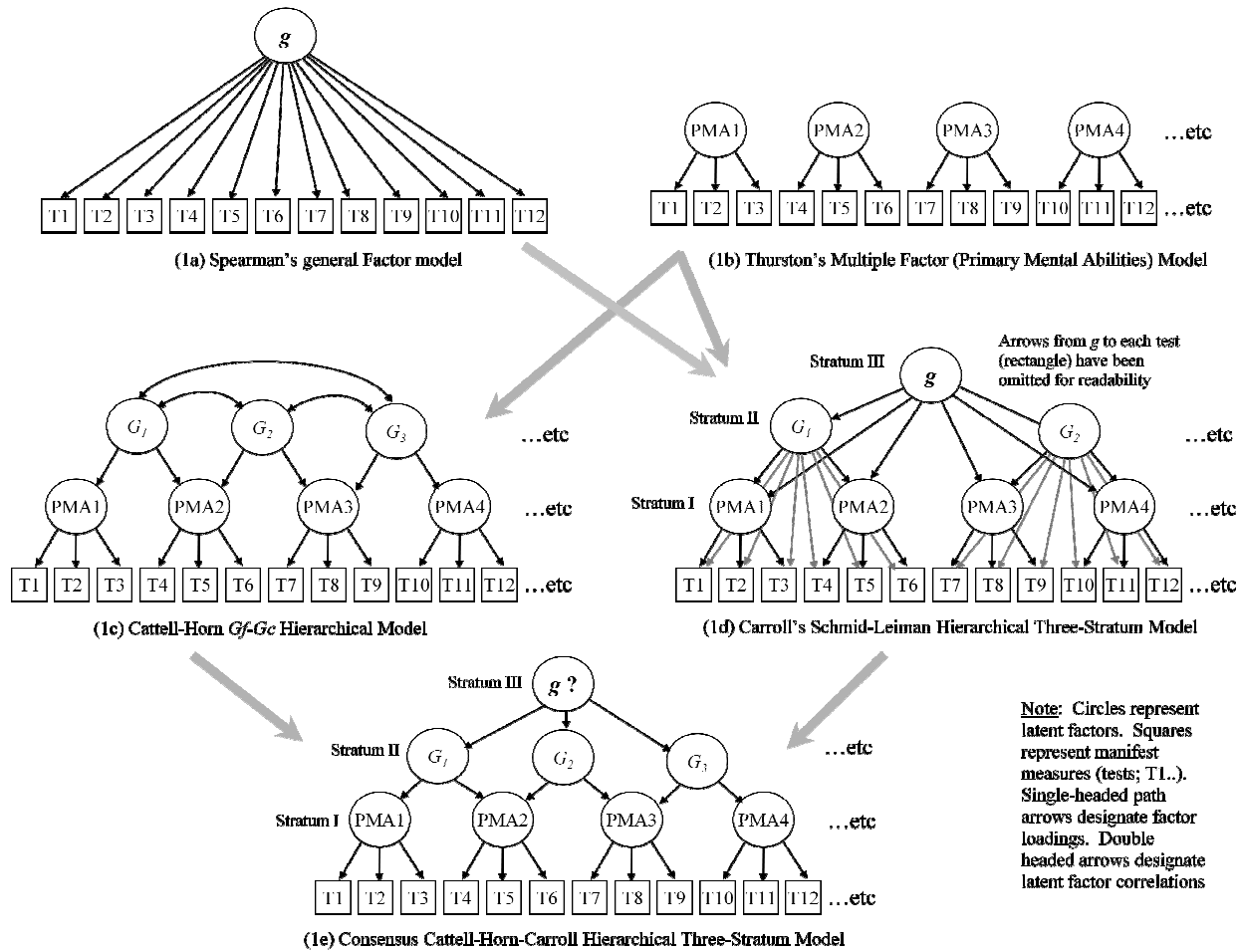
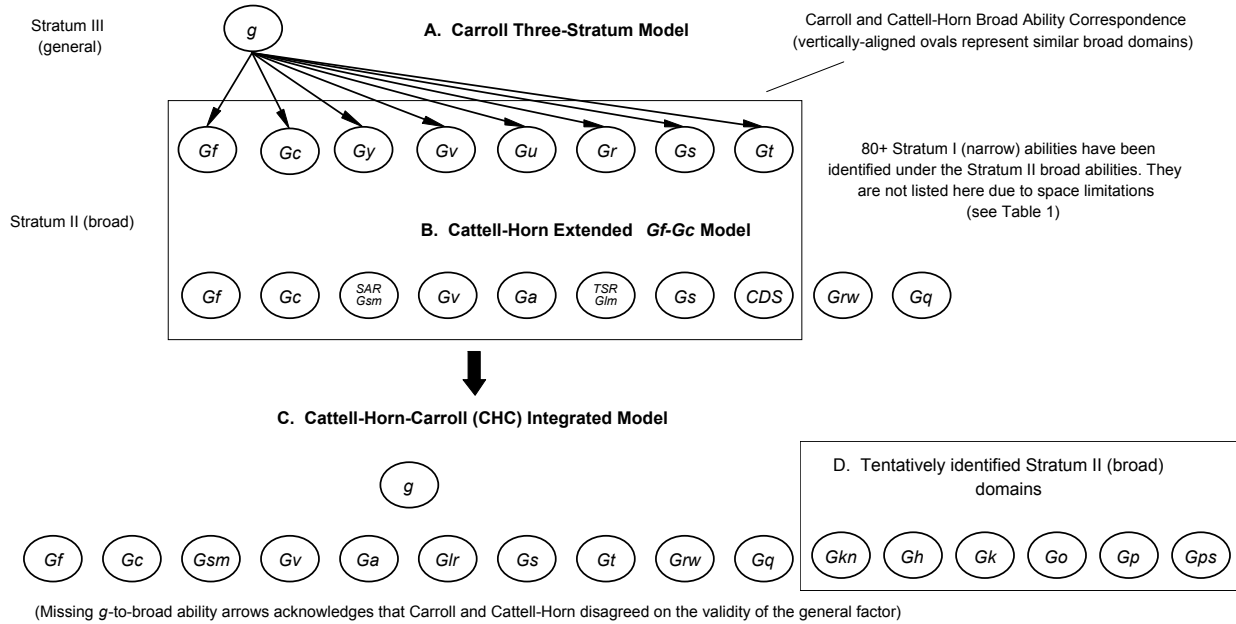


Figure 1: Major stages in the evolution of psychometric theories from Spearman's g to Cattell-Horn-Carroll (CHC) theory



CHC Broad (Stratum II) Ability Domains

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

(see Table 1 for definitions)