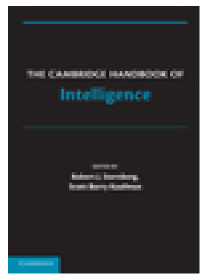

The Cambridge Handbook of Intelligence

Edited by Robert J. Sternberg, Scott Barry Kaufman

Book DOI: http://dx.doi.org/10.1017/CBO9780511977244

Online ISBN: 9780511977244

Hardback ISBN: 9780521518062

Paperback ISBN: 9780521739115

Chapter

3 - Factor-Analytic Models of Intelligence pp. 39-57

Chapter DOI: http://dx.doi.org/10.1017/CBO9780511977244.004

Cambridge University Press

CHAPTER 3

Factor-Analytic Models of Intelligence

John O. Willis, Ron Dumont, and Alan S. Kaufman

The great tragedy of Science – the slaying of a beautiful hypothesis by an ugly fact.

*Thomas Huxley**

Get your facts first, and then you can distort them as much as you please.

Attributed to Mark Twain†

Clearly, there are many ways to define intelligence. Wasserman and Tulsky (2005, p. 15) list 11 definitions provided by psychologists who responded in 1921 to a survey regarding their opinions about the definition of the term intelligence. Sternberg and Detterman (1986) provided an updated symposium with more definitions and some overlap of components. Sattler (2008, p. 223) provided an additional list of 19 different definitions that have been suggested over the years by several of the major experts in the field of psychology. Although intelligence, like Freud's "ego," is probably best thought of as a process, it is treated in much of the literature and often in professional practice as a "thing." The lack of a single, accepted definition of intelligence contributes to disagreements about how to assess it. Without agreement on the definition of intelligence – and even on whether IQ exists – it is difficult to reach agreement on how to measure intelligence. For information about the major theories of intelligence that have influenced testing, see Carroll (1993, chapter 2); Daniel (1997); Flanagan and Harrison, (2005); Kaufman (2009); McGrew and Flanagan (1998, chapter 1), Sattler (2008, chapter 7); Sternberg (2000); and Woodcock (1990). And for some of the many disputes about the construct and measurement of intelligence, see Eysenck versus Kamin (1981); Gould (1981); Herrnstein and Murray (1994); and Jacoby and Glauberman (1995), among a great many, many other sources (it is a contentious field).

* Presidential address at the British Association, "Biogenesis and abiogenesis" (1870); later published in *Collected Essays*, Vol. 8, p. 229. London, UK: Macmillan and Co., 1894. [Elibron Classics Replica Edition, Chestnut Hill, MA: Adamant Media, 2001.]

† Commonly quoted as: "First get your facts, then you can distort them at your leisure." Rudyard Kipling, An interview with Mark Twain, p. 180, From *Sea to sea: Letters of travel*, 1899, Doubleday & McClure.

Global Intellectual Ability Versus Separate Abilities

A persistent and unresolved question in both professional theories and lay conceptualizations of intelligence has been whether an individual has one, overall level of "intelligence" or, instead, what we call "intelligence" is actually a set of several separate abilities. These theorists could be characterized respectively as "lumpers" and "splitters" (McKusick, 1969). Although apparently dichotomous, this fundamental question has spawned continua of hotly debated theories.

At one end, there is the extreme lumper position that each person has a single level of cognitive ability (often referred to as *g*, as discussed later in the chapter; e.g., Jensen, 1998; Spearman, 1904). The *expression* of this intelligence may vary with different tasks, and as a function of education, sensory and motor abilities, and other influences, but the individual has one, single level of reasoning ability that will be seen on a wide variety of intelligence tests. This theoretical perspective matches the common observation that among our friends and acquaintances, some individuals are consistently pretty smart about almost everything and some are consistently incompetent and clueless. Most of us can categorize the people we know as "smart," "dumb," or something in between. Theorists and practitioners who adhere to this position tend to consider the total score on an intelligence test an approximation of the individual's overall level of intelligence, although scores will vary somewhat on different tests.

The opposite extreme, the splitter end of this continuum, is the position that there is a set of several higher order cognitive abilities that are more or less independent of each other (e.g., Cattell, 1941; Horn & Blankson, 2005; Horn & Cattell, 1966; Guilford, 1967; Thorndike, 1927; Thurstone, 1938). A person might demonstrate, for example, a high level of verbal knowledge, vocabulary, and verbal reasoning ability but be weak in visual-spatial thinking and unable to read a map or to "see" how a decorator's floor plan would translate into the actual layout of furniture in the real room. Most of us can think of acquaintances who may be terribly clever in some ways and notably incompetent in others. Theorists and practitioners who adhere to this extreme splitter position tend to ignore or deemphasize total scores on intelligence tests and focus on patterns of strengths and weaknesses.

Other splitter theorists focus their attention on different mental *processes* (rather than a set of discrete *abilities*) such as planning; attention; and dealing with information in a step-by-step, sequential process or in an all-at-once, holistic approach (e.g., Kaufman, Kaufman, Kaufman-Singer, & Kaufman, 2005; Luria, 1980; Naglieri & Das, 2005). Again, this theoretical perspective is mirrored in popular psychology. People often characterize themselves and others as, for example, either sequential (successive, auditory/sequential) or holistic (simultaneous, visual/spatial) thinkers (e.g., Kaufman, Kaufman, & Goldsmith, 1984; Silverman, 2000).

Still other splitter theorists (e.g., Gardner, 1983, 2003; Stanovich, 2009; Sternberg, 1982, 2005) object to the narrow scope of intelligence as it is measured by most existing intelligence tests. They note that the oral question-and-answer, paper-and-pencil, and picture-and-puzzle intelligence tests deemphasize or entirely omit such essential capacities as practical intelligence, creativity, artistic and musical abilities, and rational thinking.

General Intelligence – Spearman's g

British psychologist Charles Spearman (1904) proposed a conception of intelligence perhaps most widely (though by no means universally) accepted by authors and users of intelligence tests. His idea was that each person has a certain general level of intellectual ability, which the person can demonstrate in most areas of endeavor, although it will be expressed differently under different circumstances. This general intelligence is commonly referred to by the single italicized letter, *g*.

As noted above, Spearman's general ability theory is appealing on a commonsense level. One finds, for example, that some colleagues are generally pretty smart at most things while others have a lack of ability that seems to extend with equally broad application to many endeavors. There is also, as Spearman showed, statistical support for the general ability theory. Using the statistical techniques of factor analysis to examine a number of mental aptitude tests, he observed that people who performed well on one cognitive test tended to perform well on other tests, while those who scored badly on one test tended to score badly on others. Spearman demonstrated that measures of different mental abilities correlated substantially with each other. People with high verbal abilities are likely also to have high spatial and quantitative abilities, and so on. (Persons with higher IQs apparently are also likely to be taller and have more body symmetry than persons with lower ability scores – Silventoinen, Posthuma, van Beijsterveldt, Bartels, & Boomsma, 2006; Prokosch, Yeo, & Miller, 2005.) Spearman postulated that those positive correlations across different tests indicated that there must be a general function or "pool" of mental energy, which he named the general factor, or *g* (Spearman, 1904, 1927). Spearman also acknowledged specific factors(s) representing particular tests or subtests, but not generalized across tests.

Karl Holzinger and colleagues (Holzinger & Harman, 1938; Holzinger & Swineford, 1937) developed the Bi-factor theory, which,

> in its simplest form . . . is merely an extension of Spearman's Two-factor pattern to the case of group factors. The Spearman pattern is a theoretical frame of reference consisting of a general factor running through all variables and uncorrelated factors present in each variable. The Bi-factor pattern is also a theoretical frame of reference in which a general factor is assumed to run through all variables with specific factors in each variable, but in addition a number of uncorrelated group factors, each through two or more variables, are also included. The minimum number of factors of these three types for *n* variables may then be briefly summarized as follows: one general factor, *n* specific factors and *q* group factors where *q* is usually much smaller than *n*. In the modified pattern some of the group factors may overlap. (Holzinger & Swineford, 1937, p. 41)

Louis (Eliyahu) Guttman (1954, 1971), among many contributions to statistics and social sciences, applied his Radex model, an alternative to traditional factor analysis, to psychological tests (Levy, 1994). The Radex model includes a linear dimension of increasing task complexity from recall through application to inference of rules (simplex) and a circular dimension (circumplex) of correlation between tasks in numerical, figural, and verbal material sectors. Two similar tests of low complexity would be close together toward the periphery of the plane. Two tests of high complexity would be near the center, which essentially corresponds to *g*.

Most intelligence tests in use today are based, at least in part, on the general ability theory. Critics (e.g., Gould, 1981) assert that correlations with older tests based on the *g* theory are used to justify new tests based on the same theory, which, they claim, adds more circular and artificial support to the construct of *g*.

It has long been recognized that many immediate or enduring, nonintellectual influences can affect the expression of *g* (e.g., Wechsler, 1926). For instance, a math "phobia," lack of training in higher math, or an interacting combination of the two forces could prevent the successful expression of a person's full *g* in the area of mathematics.

Some problems require more than *g* for their solution. For instance, solving problems in engineering, housekeeping, teaching, farming, mechanics, and medicine usually requires specialized knowledge, skills, and ways of thinking. Further, emotions and intellect often interact, sometimes aiding and sometimes interfering with one another in solving problems, including IQ-test items (e.g., Daleiden, Drabman, & Benton, 2002; Glutting, Youngstrom, Oakland, & Watkins, 1996; Oakland, Glutting, & Watkins, 2005; Stanovich, 2009; Wechsler, 1943, 1950). For example, frustration tolerance, impulsiveness, and persistence are important components of test performance.

The *g* theory of intelligence is not necessarily linked to theories of either hereditary or environmental influences on intelligence (e.g., Eysenck vs. Kamin, 1981). The idea necessary for acceptance of the *g* theory is that intelligence operates primarily as a single capacity.

Brain damage, disease, deprivation, and disturbance are, of course, known to affect some expressions of intelligence differentially. For example, a stroke may impair one function, such as speech, while sparing others, such as drawing. Sacks (1970) offers many highly readable examples of differential effects of diseases and injuries. Springer and Deutsch (1993), Sauerwein and Lassonde (1997), and others discuss split-brain studies. Hale and Fiorello (2004), Lezak, Howieson, and Loring (2004), and Miller (2007, 2010) provide detailed textbooks on neuropsychological assessment. General ability theorists might hold that it is the expression of intelligence that is affected, and that intelligence itself is still mostly unitary, even though its application is unevenly handicapped.

For more than three-quarters of a century, Spearman's *g* theory was the only one that mattered for practical assessment of intelligence. Indeed, Spearman's *g* was at the root of Terman's (1916) Stanford-Binet adaptation of Binet's test (Binet & Simon, 1916/1980) in the United States, forming the foundation for offering only a single score, the global IQ (Kaufman, 2009). Until 1939, intelligence tests generally offered only a total score to be taken as an approximation of *g*. David Wechsler's (1939) Wechsler-Bellevue Intelligence Scale offered two IQs (Verbal and Performance) in addition to the Full Scale IQ or proxy for *g*, which inspired an industry of profile analysis as clinicians and researchers interpreted various patterns of subtest scores from diverse perspectives (e.g., Kaufman, 1979, 1994; Rapaport, Gill, & Schafer, 1945–1946; Zimmerman & Woo-Sam, 1973). Ultimately, another industry was formed dedicated to condemnation of the practice of profile interpretation – for example, McDermott, Fantuzzo, and Glutting (1990), who proclaimed, "Just say no to subtest analysis: A critique on Wechsler theory and practice." That debate continues to the present day (Flanagan & Kaufman, 2009; Lichtenberger & Kaufman, 2009; Watkins, Glutting, & Youngstrom, 2005). Ironically, Wechsler provided clinicians with a profile of IQs and subtest scaled scores to interpret – and he championed the interpretation of subtest profiles for diagnosis of brain damage and psychopathology (Wechsler, 1958) – but he always considered the Wechsler-Bellevue and all his subsequent intelligence scales to be measures of global intellectual ability, measures of *g*.

Thurstone's Primary Mental Abilities

Other theorists (e.g., Edward L. Thorndike, 1927; Thomson, 1916) have historically placed more importance on separate areas of intelligence and argued that *g* and specific factors (referred to as "*s*" by Spearman) interact to determine the expression of intelligence in different situations. The opponents of Spearman's *g* did not deny that cognitive tests tend to correlate positively (sometimes called "a condition of positive manifold"; Horn & Blankson, 2005, p. 61). Instead, they maintained that a positive manifold can occur for a variety of reasons that have nothing to do with a common factor. Nearly a century ago – the same year that Terman (1916) published the Stanford-Binet – Thomson articulated this anti-*g* argument cogently. Thomson (1916) maintained that the emergence of *g* "was a consequence of the overlap existing among discrete elements that are used to solve various intellectual tasks. Thus, the positive manifold is a consequence of relationships among discrete elements combined according to the laws of chance" (Brody, 2000, p. 30).

There are many different conceptions of the specific mental factors. In 1938, Louis L. Thurstone, an outspoken opponent of Spearman's *g*, offered a differing theory of intelligence. Thurstone, who had developed methods for scaling psychological measures, assessing attitudes, and testing theory, developed new factor analytic techniques to determine the number and nature of latent constructs within a set of observed variables. Using his new methods, Thurstone argued that Spearman's *g* resulted from a statistical artifact based upon the mathematical procedures that Spearman had used. Thurstone believed that human intelligence should not be regarded as a single unitary trait, and in its place, he proposed the theory of Primary Mental Abilities (1938), a model of human intelligence that challenged Spearman's unitary conception of intelligence. Holzinger and Harry H. Harman applied Holzinger's Bi-factor method to Thurstone's (1936) factor analysis and found "striking agreement" (Holzinger & Harman, 1938, p. 45) between Thurstone's results and their own.

Thurstone's early theory, based upon an analysis of mental test data from samples composed of people with similar overall IQs, suggested that intelligent behavior does not arise from a general factor but instead emerges from different "primary mental abilities" (Thurstone, 1938). The abilities that he described were verbal comprehension, inductive reasoning, perceptual speed, numerical ability, verbal fluency, associative memory, and spatial visualization.

British psychologist P. E. Vernon (1950) proposed a hierarchical group factor theory of the structure of human intellectual abilities, based upon factor analysis. His proposed intellectual structure had at the highest level General ability (*g*) with major, minor, and specific factors tiered below *g*. Major factors were Verbal-educational and Spatial-mechanical, while the minor group included such factors as Verbal Fluency, Numerical, and Psychomotor abilities. Specific factors (lowest in the hierarchy) referred to narrow ranges of behavior. Because Vernon's theory included both a general factor and group factors, it may be viewed as something of a compromise between Spearman's two-factor theory (which was composed of *g* and *s*, but did not include group factors) and Thurstone's multiple-factor theory (which did not have a general factor).

Guilford's Structure of Intellect Model

One prominent multifactor theorist was J. P. Guilford (1967, 1975, 1988), who devised the Structure of the Intellect (SOI) model. Guilford's theory laid out, in a three-dimensional model, five different mental operations needed to solve problems (such as *Convergent Production* or *Divergent Production*) on four different contents (such as *Symbolic* or *Figural*), yielding six kinds of products (such as *Classes* or *Relations*) for a total of 120 ($5 \times 4 \times 6 = 120$) possible intellectual factors. Guilford's model, because of the huge number of intellectual abilities it posited, was the most dramatic contrast to Spearman's unitary *g* theory.

Despite the clear distinction between Spearman's single-factor model and Guilford's multidimensional model, both suffered from a similar problem. As Kaufman (2009) notes, "If one ability was too few to build a theory on, then 120 was just as clearly too many. And Guilford did not stop at 120. He kept refining the theory, adding to its complexity. He decided that one Figural content was not enough, so he split it into figural-auditory and figural-visual (Guilford, 1975). Nor was a single memory operation adequate, so he subdivided it into memory recording (long-term) and memory retention (short-term) (Guilford, 1988). The revised and expanded SOI model now included 180 types of intelligence!" (p. 52). Guilford's model, although influential, particularly in special education and education of gifted children (e.g., Meeker, 1969), was widely and sometimes harshly criticized for lack of solid empirical support for the separate abilities (e.g., Carroll, 1968; Horn & Knapp, 1973, 1974; Vernon, 1979; Thorndike, 1963). In particular, "these researchers claimed that there wasn't enough evidence to support the existence of the independent abilities that Guilford had described" (Kaufman, 2009, p. 51). For example, "the factor analytic results that have been presented as evidence for the theory do not provide convincing support because they are based upon methods that permit very little opportunity to reject hypotheses" (Horn & Knapp, 1973, p. 33).

One Influential Synthesis – Cattell, Horn, and Carroll

Spearman (1904) had originally insisted that the separate, *s*, factors were limited to their particular tests or subtests. Eventually, though, he recognized that some *s* factors were common to multiple measures but, unlike *g*, they were not common to all measures (Spearman, 1927). The final version of Spearman's theory with the two factors, one *g* and various *s* factors (some of which applied to groups of tests), was closer to Thurstone's formulation than his original theory had been.

At the other end of our continuum, when Thurstone administered his tests to an intellectually heterogeneous group of children, he found that his seven primary abilities were *not* entirely separate; instead he found evidence of a second-order factor that he theorized might be related to *g* (Sattler, 2008). According to Ruzgis (1994), the final version of Thurstone's theory, which accounted for the presence of both a general factor and the seven specific abilities, helped lay the groundwork for future researchers who proposed hierarchical theories and theories of multiple intelligences. Thurstone's final formulation was closer than his original theoretical framework to Spearman's model. In the end, the two extremes of the lumper-splitter continuum (Spearman and Thurstone) each gravitated a bit toward the center.

Cattell and Horn's Gf-Gc Model

Probably the best known and most widely accepted theories of intellectual factors derive from the model of Raymond B. Cattell (1941) and his student, John L. Horn (1965). Cattell first proposed two types of intelligence: G*f* and G*c*, which refer, respectively, to "fluid intelligence" and "crystallized intelligence" (Cattell, 1963). Cattell and Horn and colleagues (e.g., Cattell & Horn, 1978; Horn, 1985; Horn & Blankson, 2005; Horn & Cattell 1966; Horn & Noll, 1997) – drawing on factor analytic studies and evidence from "neurological damage and aging" and "genetic, environmental, biological, and developmental variables" (Horn & Blankson, 2005, p. 45) – gradually expanded this initial bifurcation of *g* into eight or nine primary abilities. Horn (1985, 1994) argued unyieldingly against the reality of a single general ability factor (*g*), because he did not believe that research supported a unitary theory.

G*f*, *fluid intelligence*, refers to inductive, deductive, and quantitative reasoning with materials and processes that are new to the person doing the reasoning. Fluid abilities allow an individual to think and act quickly, solve novel problems, and encode short-term memories. The vast majority of fluid reasoning tasks on intelligence tests use nonverbal, relatively culture-free stimuli, but require an integration of verbal and nonverbal thinking.

G*c*, *crystallized intelligence*, refers to the application of acquired knowledge and learned skills to answering questions and solving problems presenting at least broadly familiar materials and processes. It is reflected in tests of knowledge, general information, use of language (vocabulary), and a wide variety of acquired skills (Horn & Cattell, 1966). Most verbal subtests of intelligence scales are classified primarily as measuring crystallized intelligence, However, some such subtests, like Wechsler's Similarities, clearly require fluid reasoning as well as crystallized knowledge to earn high scaled scores.

Carroll's Three-Stratum Hierarchy

John B. Carroll (1993) undertook a truly staggering reanalysis of all of the usable correlational studies of mental test data that he could find. He winnowed a collection of about 1,500 studies down to a set of 461 datasets that met four technical criteria (Carroll, 1993, pp. 78–80, 116) and then subjected the data from those studies to a uniform process of reanalysis by exploratory factor analysis (pp. 80–91). Carroll noted that this massive project was "in a sense an outcome of work I started in 1939, when . . . I became aware of L. L. Thurstone's research on what he called 'primary mental abilities' and undertook, in my doctoral dissertation, to apply his factor-analytic techniques to the study of abilities in the domain of language" (1993, p. vii; see also Carroll, 1943). As a result of his reanalysis of the 461 data sets, Carroll presented extensive data in the domains of Language, Reasoning, Memory and Learning, Visual Perception, Auditory Reception, Idea Production, Cognitive Speed, Knowledge and Achievement, Psychomotor Abilities, Miscellaneous Domains of Ability and Personal Characteristics, and Higher-Order Factors of Cognitive Ability (1993, p. 5). Based on his data, Carroll (1993, pp. 631–655) presented "A Theory of Cognitive Abilities: The Three-Stratum Theory" with "*narrow* (stratum I), *broad* (stratum II), and *general* (stratum III)" (p. 633) abilities. See also Carroll (1997/2005) for further discussion.

Integration of Horn-Cattell and Carroll Models to Form CHC Theory

The remarkable similarity between Carroll's *broad* stratum II abilities and Cattell and Horn's expanded G*f*-G*c* abilities suddenly became apparent at a meeting in March 1996 convened by the publisher of the Woodcock-Johnson Psycho-Educational Battery (Woodcock & Johnson, 1977) to begin the process of developing the Woodcock-Johnson – Revised (Woodcock & Johnson, 1989). Kevin McGrew (2005) describes this "fortuitous" meeting that included Richard Woodcock, John Horn, and John Carroll, among other important figures in test theory and development, including McGrew. McGrew considers that meeting the "flash point that resulted in *all* subsequent theory-to-practice bridging events leading to today's CHC theory and related assessment developments" (p. 144).

"CHC" stands for "Cattell-Horn-Carroll," a synthesis of the work of Cattell and Horn with that of Carroll. McGrew (2005, p. 148) believes that the term and abbreviation "Cattell-Horn-Carroll theory" and "CHC" were first published in Flanagan, McGrew, and Ortiz (2000) and first formally defined in print in his and Woodcock's technical manual for the third edition of the Woodcock-Johnson battery (McGrew & Woodcock, 2001). CHC theory synthesizes two of the most widely recognized theories of intellectual abilities (McGrew, 2005; Sternberg & Kaufman, 1998).

Although Horn and Carroll agreed to the use of the term Cattell-Horn-Carroll (McGrew, 2005, p. 149), Horn and Carroll always disagreed sharply about *g* or the general stratum III (McGrew, 2005, p. 174). Horn, like Thurstone in his earlier formulations, consistently and adamantly maintained that there was no single *g*. Carroll always considered *g* or stratum III essential to his hierarchical, three-stratum theory.

Carroll (1993, 1997) stated that "there are a fairly large number of distinct individual differences in cognitive ability, and that the relationships among them can be derived by classifying them into three different strata: stratum I, 'narrow' abilities; stratum II, 'broad' abilities; and stratum III, consisting of a single 'general' ability" (Carroll, 1997, p. 122). Carroll's model, although similar to that proposed by Cattell and Horn, differs in several substantial ways. First, as noted, Carroll included at stratum III the general intelligence factor (*g*) because he believed that the evidence for such a factor was overwhelming. Second, where Cattell and Horn differentiate Quantitative knowledge as a separate Gf-Gc factor, in this case G*q*, Carroll believed quantitative ability was best subsumed as a narrow G*f* ability. Third, while the Cattell-Horn model included measures of Reading and Writing as a combined, separate factor (G*rw*), Carroll believed these to be narrow abilities subsumed in the G*c* factor.

Applications of CHC Theory – Cross-Battery Assessment and Test Development

CHC theory provided the basis for the McGrew, Flanagan, and Ortiz integrated Cross-Battery Approach to assessment (see, for example, Flanagan & McGrew, 1997; Flanagan, McGrew, & Ortiz, 2000; Flanagan, Ortiz, & Alfonso, 2007; Flanagan, Ortiz, Alfonso, & Mascolo, 2006; McGrew, 1997; and McGrew & Flanagan, 1998). These authors attempted – on the basis of factor analytic studies, especially Carroll's (1993) massive effort, and on the basis of expert judgments of newer tests for which factor analytic data were lacking – to characterize each of a great many subtests from cognitive ability scales (and achievement tests) as assessing one or more narrow (stratum I) and broad (stratum II) CHC abilities. They provided detailed guidelines for using a core cognitive ability scale along with subtests from one or more additional instruments to assess all of the CHC broad abilities with measures of at least two different narrow abilities. Additional testing would be required if the scores on the two narrow ability measures within a broad ability differed significantly from each other, raising the possibility of different levels of capacity on narrow abilities, rather than a unitary level of skill on the broad ability.

Although the CHC Cross-Battery Approach quickly gained many adherents among evaluators, it does not meet with universal approval. There was, for example, a lively debate in the journal *Communiqué*: Floyd (2002) offered "recommendations for school psychologists" for using the CHC Cross-Battery Approach. Watkins, Youngstrom, & Glutting, 2002) responded with "Some cautions concerning cross-battery assessment," to which Ortiz & Flanagan (2002a, 2002b) replied with their own "cautions concerning 'some cautions.'" Watkins, Glutting, and Youngstrom (2002) were "still concerned."

Watkins, Youngstrom, and Glutting wrote that the CHC Cross-Battery Approach was "well articulated and noteworthy in many respects" (2002, p. 16), but raised eight concerns, including among others, whether scores from different tests with different norming samples and other variations were comparable with one another; the effects of taking subtests out of their usual context and sequence, differential practice and other effects; the lack of factor analytic studies of batteries of many cognitive tests given to large; representative, national samples and the consequent use of an expert consensus process to assign narrow and broad abilities to subtests of new instruments; ipsative interpretation using differences between scores and the examinee's own mean score rather than strictly normative scores; and the lack of attention to *g* in the CHC Cross-Battery assessment model.

The CHC Cross-Battery advocates contended that modern standards and practices for test norming (including varying the administration order of subtests on some tests) and the use of only recently normed tests; reliance on Carroll's (1993) and other factor analytic studies; and high levels of interscorer reliability among judgments by their panels of experts obviated the concerns. They noted that the CHC Cross-Battery Approach uses normative, not ipsative scores, although ipsative comparisons are mentioned in some publications on the CHC Cross-Battery Approach.

CHC theory also, to varying degrees, contributed to the structure of many recent tests of cognitive ability. The Woodcock-Johnson Psycho-Educational Battery – Revised (WJ-R; Woodcock & Johnson, 1989; see also Woodcock, 1990, 1993, 1997) and Woodcock-Johnson III (WJ III; Woodcock, McGrew, & Mather, 2001) are explicitly based on CHC theory, and the WJ III attempts to measure the nine most commonly agreed upon CHC broad (stratum II) abilities. Some other cognitive ability tests with very explicit CHC foundations include the Kaufman Assessment Battery for Children, second edition (KABC-II; Kaufman & Kaufman, 2004) and Stanford-Binet Intelligence Scale, fifth edition (SB 5; Roid, 2003). CHC abilities are cited in the test manuals to help explain and describe scales and subtests for many tests, including the Differential Ability Scales, second edition (DAS-II: Elliott, 2007), the Leiter International Performance Scale – Revised (LIPS-R; Roid & Miller, 1997), the Reynolds Intellectual Assessment Scales (RIAS; Reynolds & Kamphaus, 2003), and recent editions of the Wechsler intelligence scales, such as the Wechsler Adult Intelligence Scale – fourth edition (WAIS-IV; Wechsler, 2008), Wechsler Intelligence Scale for Children – fourth edition (WISC-IV; Wechsler, 2003), and Wechsler Preschool and Primary Scale of Intelligence – third edition (WPPSI-III; Wechsler, 2002). There is a growing body of research showing relationships between various CHC factors and different aspects of school achievement (e.g., Evans, Floyd, McGrew, & Leforgee, 2002; Floyd, Evans, & McGrew, 2003; Hale, Fiorello, Dumont, Willis, Rackley, & Elliott, 2008; Hale, Fiorello, Kavanagh, Hoeppner, & Gaitherer, 2001).

Cognitive Abilities – What's in a Name?

CHC theory continues to evolve. Complete agreement has not quite been reached on the broad (stratum II) abilities, and the narrow (stratum I) abilities within each broad ability are occasionally redefined. Current formulations can be found in Flanagan, Ortiz, Alfonso, and Mascolo (2006) and Flanagan, Ortiz, and Alfonso (2007). Those books, and others cited earlier, classify a great many intelligence and achievement test subtests by broad (stratum II) and narrow (stratum I) CHC abilities on the basis of factor analytic research and surveys of expert opinion. The names and the abbreviations or symbols for the abilities are taken, with alterations, from Carroll, 1993, who observed (p. 644), "The naming of a factor in terms of a process, or the assertion that a given process or component of mental architecture is involved in a factor, can be based only on inferences and makes little if any contribution to explaining or accounting for that process unless clear criteria exist for defining and identifying processes."

Even more broadly, we need to be careful not to confuse verbal names for factors with the factor analytic bases for them. For example, G*v* has been referred to as, among other things, "visual-spatial thinking," which sounds like a high-level cognitive process, and "visual perception," which sounds much more physiological than intellectual. By either name, it is the same G*v*, defined by loadings of various subtests on the same factor, and we should not be distracted, biased, or misled by the verbal name assigned by an author. For example, when Cohen (1959) made a tremendous contribution to the field by publishing his factor analysis of the Wechsler Intelligence Scale for Children (WISC; Wechsler, 1949), he also, we believe, inadvertently caused decades of misunderstanding by assigning the name "freedom from distractibility" to a factor consisting of the Arithmetic, Digit Span, and Coding subtests. Generations of psychologists and educators consequently persisted in the misguided belief that those subtests were definitively diagnostic of attention deficit disorder. Kaufman (1979) tried to resolve this confusion by neutrally calling his derived score for those three subtests simply "the third factor," but in our personal experience, the misunderstanding remained robust. This cautionary tale might inspire us to take advantage of the more-or-less implication-free abbreviations and symbols offered by current formulations of CHC theory. The following discussion draws heavily on presentations in Carroll (1993); Flanagan and McGrew (1997); Flanagan, McGrew, and Ortiz (2000); Flanagan, Ortiz, and Alfonso, 2007; Flanagan, Ortiz, Alfonso, and Mascolo (2006); McGrew, 1997; and McGrew and Flanagan (1998).

Definitions of CHC Abilities

Fluid and crystallized intelligence, described earlier, were the original Cattell-Horn G*f*-G*c* factors. As noted, over the years, the original dichotomous G*f*-G*c* theory was expanded to include additional abilities. These additional broad (stratum II) abilities are defined here.

G*v*, or *visual-spatial thinking*, involves a range of visual processes, ranging from fairly simple visual perceptual tasks to higher level, visual, cognitive processes. Woodcock and Mather (1989) define G*v* in part: "In Horn-Cattell theory, 'broad visualization' requires fluent thinking with stimuli that are visual in the mind's eye." Although G*f* tasks are also often nonverbal (e.g., matrix tests), G*v* does not include the aspect of dealing with novel stimuli or applying novel mental processes that characterize G*f* tasks. Many writers seem to consider G*v* a relatively low-level cognitive ability, more perceptual than intellectual. However, the "fluent thinking with stimuli that are visual in the mind's eye" may well be a higher level intellectual process on a par with G*c* and G*f* (see, for example, Johnson & Bouchard, 2005, and Johnson, te Nijenhuis, & Bouchard, 2007, who differentiate perceptual from image rotation abilities). Engineers, auto mechanics, architects, nuclear physicists, sculptors, carpenters, and parts department managers all use G*v* to deal with the demands of their jobs. Elliott (2007), for example, made two subtests each of G*f*, G*c*, and G*v* abilities the Core subtests for the General Conceptual Ability summary score for the School-Age and Upper Early Years levels of the Differential Ability Scales, second edition. Other CHC abilities are included among the Diagnostic subtests, but are not counted in the General Conceptual Ability score.

G*a*, *auditory processing*, involves tasks such as recognizing similarities and differences between sounds; recognizing degraded spoken words, such as words with sounds omitted or separated (e.g., "tel – own" and /t/ ĕ /l/ ĕ /f/ ō /n/ both as "telephone"); and mentally manipulating sounds in spoken words (e.g., "say *blend* without the /l/ sound" or "change the ĕ in *blend* to ĭ"). Phonemic awareness skills, terribly important for acquisition of reading skills (Rath, 2001), are G*a* tasks.

G*s*, *processing speed* or attentional speediness, refers to measures of clerical speed and accuracy, especially when there is pressure to maintain focused attention and concentration.

G*t*, *decision/reaction time or speed*, reflects the immediacy (quickness) with which an individual can react and make a decision (decision speed) to typically simple stimuli. It can be difficult to distinguish between G*s* tasks, which are relatively common on intelligence tests, and G*t* tasks, which are more often found on computerized neuropsychological measures of vigilance and reaction time. G*s* tasks generally require a sustained effort over at least two or three minutes and simply measure the number of simple items completed (or number right minus number wrong) for the entire span of time. G*t* tasks are more likely to measure response speed to each item or a few items.

G*sm*, *short-term or immediate memory*, refers to the ability to take in and hold information in immediate memory and then to use it within a few seconds. Given the relatively small amount of information that can be held in short-term memory, information is typically retained for only a short period of time before it is lost. When additional tasks are required that tax an individual's short-term memory abilities, information in short-term memory is either lost or transferred and stored as acquired knowledge through the use of long-term storage and retrieval (G*lr*). G*sm* is divided in current CHC formulations into memory span (MS) and working memory (MW) with a distinction between simple recall (MS) (e.g., repeating increasing long series of dictated digits) and mental manipulation of material held in short-term memory (MW) (e.g., repeating the dictated series in reversed sequence). This is another example of the difficulty with verbal labels for abilities, since "working memory" is used by many authors to mean not MW, but MS, particularly with reference to brief retention on the way to long-term storage. The different meanings of the terms can cause considerable confusion. Factor analyses have indicated that short-term visual memory (such as recognizing in a group of pictures the one picture that had been seen earlier) is a narrow ability within G*v* rather than G*sm*.

G*lr*, *long-term storage and retrieval*, involves memory storage and retrieval over longer periods of time than G*sm*. How much longer varies from task to task. It is important to note that G*lr* is referring to the *efficiency* of what is stored, not *what* is stored. G*lr* is usually measured with controlled learning tasks in which the efficiency of learning – for example, rebus symbols for words – is assessed during the learning, and then, on some tests, retention is assessed with a delayed recall measure.

G*rw includes reading and writing abilities*, which were part of G*c* in Carroll's formulation. The narrow, stratum I abilities within G*rw* may not be sufficiently detailed to satisfy educators specializing in literacy.

G*q*, *knowledge*, is distinct from the quantitative reasoning that is a narrow ability within G*f*.

The last two broad abilities raise the question of the distinction between "ability" and "achievement." Carroll (1993, p. 510, emphasis in the original) discusses this problem: "It is hard to draw the line between factors of cognitive abilities and factors of achievement. Some will argue that *all* cognitive abilities are in reality learned achievements of one kind or another." Carroll suggests that we "conceptualize a continuum that extends from the most general abilities to the most specialized types of knowledges." Flanagan, Ortiz, Alfonso, and Mascolo (2002, p. 21) quote Carroll (1993, p. 510) and then also Horn (1988, p. 655), "Cognitive abilities are measures of achievements, and measures of achievements are just as surely measures of cognitive ability." They reach the same conclusion as Carroll: "Thus, rather than conceiving of cognitive abilities and academic achievements as mutually exclusive, they may be better thought of as lying on an *ability continuum* that has the most general types of abilities at one end and the most specialized types of knowledge at the other" (Carroll, 1993).

Other Formulations

Although they are slightly or substantially outside the factor analytic focus of this chapter, there are other important theories and models that bear mention.

Planning, Attention, Simultaneous, Successive (PASS)

Building on the work of Russian psychologist, A. R. Luria (1966, 1973, 1990), J. P. Das, Jack Naglieri, and colleagues (e.g., Das, Kirby, & Jarman, 1979; Naglieri & Das, 2002; 2005); have developed the Planning, Attention, Simultaneous, Successive (PASS) theory of intelligence. Luria posited three functional units or "blocks": arousal and attention (the Attention in PASS), representing Luria's Block 1; taking in, processing, and storing information (the Simultaneous and Successive processes in PASS), or Block 2 coding processes; and synthesizing information and regulating behavior (the Planning in PASS), which are the executive functions associated with Block 3.

The Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983; Kaufman, Kaufman, & Goldsmith, 1984) was a pioneering test based on Simultaneous versus Sequential (Successive) processing, the components of Luria's second processing unit (Block 2). The second edition of the Kaufman Assessment Battery for Children (KABC-II; Kaufman & Kaufman, 2004; Kaufman, Kaufman, Kaufman-Singer, & Kaufman, 2005) is uniquely designed to permit interpretation on the basis of four Luria-based processes or on the basis of five CHC factors: Sequential processing or G*sm*, Simultaneous processing or G*v*, Learning or G*lr*, Planning or G*f*, and G*c*.

Naglieri and Das's (1997) Cognitive Assessment System (CAS) "is built strictly on the Planning, Attention, Simultaneous, and Successive (PASS) theory" (Naglieri, 2005, p. 441). There are three Planning, three Attention, three Simultaneous, and four Successive subtests.

As with CHC theory, there is evidence of correlations of PASS measures with different aspects of educational achievement. There is also evidence of the utility of PASS profiles for planning instruction (e.g., Naglieri & Johnson, 2000). Differences between scores of African American and Euro-American students are notably smaller on the PASS-based CAS and

KABC-II than on other comprehensive cognitive ability tests in current use (Kaufman & Kaufman, 2004; Naglieri & Das, 1997).

Triarchic Theory

Many experts (e.g., Robert Sternberg, 1982, 1985; 2003, 2005; Howard Gardner, 1983, 1999); and Keith Stanovich, 2009) (also see Stanovich, this volume) argue that none of the theories discussed earlier goes far enough. Sternberg argues for recognition of "successful intelligence [which] is (1) the use of an integrated set of abilities needed to attain success in life, however an individual defines it, within his or her sociocultural context. People are successfully intelligent by virtue of (2) recognizing their strengths and making the most of them, at the same time that they recognize their weaknesses and find ways to correct or compensate for them. Successfully intelligent people (3) adapt to, shape, and select environments through (4) finding a balance in their use of analytical, creative, and practical abilities (Sternberg, 1997, 1999)" (Sternberg, 2005, p. 104). Although not strictly speaking a factor analytic theory of intelligence, Sternberg's theory is supported by studies showing the "factorial separability of analytic, creative, and practical abilities" (Sternberg, 2005, pp. 104–105). Sternberg and the Rainbow Project Collaborators (2006) investigated the use of the multiple-choice Sternberg Triarchic Abilities Test (STAT; Sternberg, 1993; Sternberg & Clinkenbeard, 1995; Sternberg, Ferrari, Clinkenbeard, & Grigorenko, 1996) and several other measures of the same domains (open-ended, performance measures of creativity and performance measures of practical skills) to improve prediction of college grade-point averages (GPA) above the prediction based on SAT scores and high school GPA alone. "The triarchic measures predict an additional 8.9% to college GPA beyond the initial 15.6% contributed by the SAT and high school GPA. These findings, combined with the substantial reduction of between-ethnicity differences, made a compelling case for furthering the study of the measurement of analytical, creative, and practical skills for predicting success in college" (Sternberg & the Rainbow Project Collaborators, 2006, p. 344). The authors pointed out several relatively minor methodological limitations in their study and anticipated that "Over time, still better measures perhaps will be created" (Sternberg & the Rainbow Project Collaborators, 2006, p. 347). Sternberg also points to evidence of effective instructional interventions based on the theory. The triarchic theory of successful human intelligence expands considerably the domain of "intelligence" beyond what is measured by most current tests. We believe that Sternberg's theory comes much closer to Wechsler's famous definition of intelligence ["the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment" (Wechsler, 1958, p. 7)] than do any of any of Wechsler's own intelligence tests.

Multiple Intelligences

Gardner argues for the existence of at least eight "intelligences," including linguistic, logical-mathematical, musical, spatial, bodily-kinesthetic, naturalistic, interpersonal, and intrapersonal, each meeting the requisite two biological, two developmental psychological, two traditional psychological, and two logical criteria to qualify as *intelligences* (Gardner, 1993). "The identification of intelligences is based on empirical evidence and can be revised on the basis of new empirical findings" (Gardner, 1994, 2003), quoted in Chen and Gardner (2005, p. 79). Gardner's multiple intelligences are difficult to measure, especially as Gardner insists on measuring various aspects of each intelligence; using a variety of media, including physical and social activities, that are suited to the various intelligences; engaging the child in meaningful activities and learning; assuring comfortable familiarity of the child with the materials and activities; putting the activities into contexts that have ecological validity and relevance for instruction; and creating complete profiles of intelligences that can be used to support teaching and learning (Chen & Gardner, 2005, pp. 82–85). Nonetheless, several assessment programs have been created, including the Spectrum Assessment System (Chen, Isberg, & Krechevsky, 1998; Chen, Krechevsky, & Viens, 1998; Krechevsky, 1991, 1998) and Bridging: Assessment for Teaching (McNamee & Chen, 2004). These observational assessment systems include focus on activities as well as children and yield detailed reports. There is evidence that individual children do perform at different levels in the various domains and that performance improves with instruction (e.g., Chen & Gardner, 2005) and that at least six of the multiple intelligences do not correlate highly with each other (Adams, 1993), a finding that support's Gardner's formulation. However, it appears to be difficult to directly assess the validity of Gardner's eight aptitudes as intelligences (e.g., Sternberg, 1991).

Rationality

Stanovich (2009) agrees with Sternberg and Gardner that the aspects of intelligence measured by traditional tests, which he terms "MAMBIT (to stand for the mental abilities measured by intelligence tests)" (p. 13), are too narrow. He focuses particularly on the absence of measures of rational thinking (e.g., Sternberg, 2002). However, rather than including rational thinking and other abilities in a definition of "intelligence," Stanovich argues for separating MAMBIT from other abilities, such as rational decision making, Sternberg's three components of successful intelligence, and Gardner's eight intelligences. He suggests that calling abilities other than MAMBIT "intelligence" increases the power of the traditional conception of intelligence in the popular mind and that rational thinking and other important abilities should receive greater attention as a result of narrowing, not broadening, the popular conception of "intelligence" or MAMBIT. Although the term, MAMBIT, seems unlikely to catch on, the argument has some appeal.

A Parting Thought

Factor-based theories of intelligence have proliferated since Spearman (1904) started the ball rolling more than a century ago. The once-extreme "lumper-splitter" dichotomy has became less extreme and the pendulum has rested somewhere between the two ends, though decidedly closer to the Thurstone than the Spearman end. The uneasy balance between *g* and multiple abilities is probably best reflected by CHC theory, which reflects an integration of the life's work of John Carroll (a believer in *g*) and John Horn (a devout nonbeliever), and forms the foundation of most contemporary "IQ tests." We believe that CHC theory has important positive features and merits a key role in the assessment of intelligence. But, however well researched CHC theory may be, it reflects only one-third of Sternberg's theory, and perhaps a similar portion of Gardner's theory – but, as Stanovich aptly points out, MAMBIT is too narrow. At present, CHC theory and, to a lesser extent, Luria's neuropsychological theory, provide the theoretical basis of virtually all major tests of cognitive abilities. It is time for that status quo to change. The time has come for developers of individual clinical tests of intelligence to broaden their basis of test construction beyond the analytic dimension of Sternberg's triarchic theory and to begin to embrace the assessment of both practical intelligence and creativity.

References

Adams, M. (1993). *An empirical investigation of domain-specific theories of preschool children's cognitive abilities*. Unpublished doctoral dissertation, Tufts University.

Binet, A., & Simon, T. (1916/1980). *The development of intelligence in children*, with marginal notes by Lewis M. Terman and preface by Lloyd M. Dunn. Translated by Elizabeth S. Kite with an introduction by Henry Goddard. Facsimile limited edition issued by Lloyd M. Dunn. Nashville, TN: Williams.

Brody, N. (2000). History of theories and measurements of intelligence. In R. J. Sternberg

(Ed.), *Handbook of intelligence* (pp. 16–33). New York, NY: Cambridge University Press.

Carroll, J. N. (1968). Review of the nature of human intelligence by J. P. Guilford. *American Educational Research Journal*, 73, 105–112.

Carroll, J. B. (1985). Exploratory factor analysis: A tutorial. In D. K. Detterman (Ed.), *Current topics in human intelligence* (Vol. 1, pp. 25–58). Norwood, NJ: Ablex.

Carroll, J. B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge, UK: Cambridge University Press.

Carroll, J. B. (1997). The three-stratum theory of cognitive abilities. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 122–130). New York, NY: Guilford Press.

Cattell, R. B. (1941). Some theoretical issues in adult intelligence testing. *Psychological Bulletin*, 38, 592.

Cattell, R. B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology*, **54**, 1–22.

Cattell, R. B., & Horn, J. L. (1978). A check on the theory of fluid and crystallized intelligence with description of new subtest designs. *Journal of Educational Measurement*, **15**, 139–164.

Chen, J-Q., & Gardner, H. (2005). Assessment based on multiple-intelligence theories. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 77–102). New York, NY: Guilford Press.

Chen, J. Q., Isberg, E., & Krechevsky, M. (Eds.). (1998). *Project Spectrum: Early learning activities*. New York, NY: Teachers College Press.

Chen, J. Q., Krechevsky, M., & Viens, J. (1998). *Building on children's strengths: The experience of Project Spectrum*. New York. NY: Teachers College Press.

Daleiden, E., Drabman, R. S., & Benton, J. (2002). The guide to the assessment of test session behavior: Validity in relation to cognitive testing and parent-reported behavior problems in a clinical sample. *Journal of Clinical Child Psychology*, **31**, 263–271.

Daniel, M. H. (1997). Intelligence testing: Status and trends. *American Psychologist*, **52**(10), 1038–1045.

Das, J. P., Kirby, J. R., & Jarman, R. F. (1979). *Simultaneous and successive cognitive processes*. New York, NY: Academic Press.

Elliott, C. D. (2007). *Differential Ability Scales – second edition*. San Antonio, TX: Psychological Corporation.

Evans, J. J., Floyd, R. G., McGrew, K. S., & Leforgee, M. H. (2002). The relations between measures of Cattell-Horn-Carroll (CHC) cognitive abilities and reading achievement during childhood and adolescence. *School Psychology Review*, **31**, 246–262.

Eysenck, H. J., vs. Kamin, L. J. (1981). *The intelligence controversy*. Hoboken, NJ: Wiley-Interscience.

Flanagan, D. P., & Harrison, P. L. (Eds.). (2005). *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed.). New York, NY: Guilford Press.

Flanagan, D. P., & Kaufman, A. S. (2009). *Essentials of WISC-IV assessment* (2nd ed.). Hoboken, NJ: Wiley.

Flanagan, D. P., & McGrew, K. S. (1997). A cross-battery approach to assessing and interpreting cognitive abilities: Narrowing the gap between practice and cognitive science. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment* (ch. 17, pp. 314–325). New York: Guilford Press.

Flanagan, D. P, McGrew, K. S., & Ortiz, S. O. (2000). *The Wechsler Intelligence Scales and Gf-Gc theory: A contemporary approach to interpretation*. Boston: Allyn & Bacon.

Flanagan, D. P., Ortiz, S. O., & Alfonso, V. (2007). *Essentials of cross-battery assessment* (2nd ed.). Hoboken, NJ: Wiley.

Flanagan, D. P., Ortiz, S. O., Alfonso, V. & Mascolo, J. T. (2002). *The achievement test desk reference: Comprehensive assessment of learning disabilities*. Boston, MA: Allyn & Bacon.

Flanagan, D. P., Ortiz, S. O., Alfonso, V., & Mascolo, J. T. (2006). *Achievement test desk reference (ATDR-II): A guide to learning disability identification (2nd ed.)*. Hoboken, NJ: Wiley.

Floyd, R. (2002). The Cattell-Horn-Carroll (CHC) Cross-Battery Approach: Recommendations for school psychologists. *Communiqué*, **30**(5), 10–14.

Floyd, R. G., Evans, J. J., & McGrew, K. S. (2003). Relations between measures of Cattell-Horn-Carroll (CHC) cognitive abilities and mathematics achievement across the school-age years. *Psychology in the Schools*, **60**(2), 155–171.

Gardner, H. (1983). *Frames of mind*. New York, NY: Basic Books.

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences* (10th anniversary ed.). New York, NY: Basic Books.

Gardner, H. (1994). Multiple intelligences theory. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 740–742). New York, NY: Macmillan.

Gardner, H. (1999). *Intelligence reframed: Multiple intelligences for the 21st century*. New York, NY: Basic Books.

Gardner, H. (2003, April). *Multiple intelligences after twenty years*. Paper presented at the annual meeting of the American Education Research Association, Chicago, IL.

Glutting, J. J., Youngstrom, E. A., Oakland, T., & Watkins, M. W. (1996). Situational specificity of generality of test behaviors for examples of normal and referred children. *School Psychology Review*, **25**, 64–107.

Gould, S. J. (1981). *The mismeasure of man*. New York, NY: Norton.

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGraw-Hill.

Guilford, J. P. (1975). Varieties of creative giftedness, their measurement and development. *Gifted Child Quarterly*, **19**, 107–121.

Guilford, J. P. (1988). Some changes in the structure-of-intellect model. *Educational and Psychological Measurement*, **48**, 1–4.

Guttman, L. (1954). A new approach to factor analysis: The radix. In P. F. Lazarfeld (Ed.), *Mathematical thinking in the social sciences*. New York, NY: Free Press.

Guttman, L. (1971). Measurement as structural theory. *Psychometrika*, **36**, 329–347.

Hale, J. B., & Fiorello, C. A. (2004). *School neuropsychology: A practitioner's handbook*. New York, NY: Guilford Press.

Hale, J. B, Fiorello, C. A., Dumont, R., Willis, J. O., Rackley, C., & Elliott, C. (2008). Differential Ability Scales-Second Edition (neuro)psychological predictors of math performance for typical children and children with math disabilities. *Psychology in the Schools*, **45**(9), 838–858.

Hale, J. B., Fiorello, C. A., Kavanagh, J. A., Hoeppner, J. B., & Gaitherer, R. A. (2001). WISC-III predictors of academic achievement for children with learning disabilities: Are global and factor scores comparable? *School Psychology Quarterly*, **16**(1), 31–35.

Herrnstein, R. J., & Murray, C. (1994). *The bell curve: Intelligence and class structure in American life*. New York, NY: Simon & Schuster (Free Press Paperbacks).

Holzinger, K. J., & Harman, H. H. (1938). Comparison of two factorial analyses. *Psychometrika*, **3**, 45–60.

Holzinger, K. J., & Swineford, F. (1937). The bifactor method. *Psychometrika*, **2**, 41–54.

Horn, J. L. (1965). *Fluid and crystallized intelligence: A factor analytic study of the structure among primary mental abilities*. Unpublished doctoral dissertation, University of Illinois.

Horn, J. L. (1985). Remodeling old models of intelligence. In B. B. Wolman (Ed.), *Handbook of intelligence: Theories, measurements, and applications* (pp. 267–300). Hoboken, NJ: Wiley.

Horn, J. L. (1988). Thinking about human abilities. In J. R. Nesselroade & R. B. Cattell (Eds.), *Handbook of multivariate psychology* (rev. ed., pp. 645–685). New York, NY: Academic Press.

Horn, J. L. (1994). The theory of fluid and crystallized intelligence. In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 433–451). New York, NY: Macmillan.

Horn, J. L., & Blankson, B. (2005). Foundations for better understanding of cognitive abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment* (2nd ed., pp. 41–68). New York, NY: Guilford Press.

Horn, J. L., & Cattell, R. B. (1966). Refinement and test of the theory of fluid and crystallized general intelligences. *Journal of Educational Psychology*, **57**, 253–270

Horn, J. L., & Knapp, J. R. (1973). On the subjective character of the empirical base of Guilford's structure of intellect model. *Psychological Bulletin*, **80**, 33–43.

Horn, J. L., & Knapp, J. R. (1974). Thirty wrongs do not make a right. *Psychological Bulletin*, **81**, 502–504.

Horn, J. L., & Noll, J. (1997). Human cognitive capabilities: Gf-Gc theory. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 53–91). New York, NY: Guilford Press.

Jacoby, R., & Glauberman, N. (Eds.). (1995). *The Bell Curve debate*. New York, NY: Times Books.

Jensen, A. R. (1998). *The g factor: The science of mental ability*. Westport, CT: Praeger.

Johnson, W., & Bouchard, T. J. (2005). The structure of human intelligence: It is verbal, perceptual, and image rotation (VPR), not fluid and crystallized. *Intelligence*, **33**, 393–416.

Johnson, W., te Nijenhuis, J., & Bouchard, T.J. (2007). Replication of the hierarchical visual-perceptual-image rotation model in de Wolff and Buiten's (1963) battery of 46 tests of mental ability. *Intelligence*, **35**, 69–81.

Kamphaus, R. W., Winsor, A. P., Rowe, E. W., & Kim, S. (2005). A history of intelligence assessment. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 23–38). New York, NY: Guilford Press.

Kaufman, A. S. (1979). *Intelligent testing with the WISC-R*. New York, NY: Wiley.

Kaufman, A. S. (1994). *Intelligent testing with the WISC-III*. New York, NY: Wiley.

Kaufman, A. S. (2009). *IQ Testing 101*. New York, NY: Springer.

Kaufman, A. S., & Kaufman, N. L. (1983). *The Kaufman Assessment Battery for Children*. Circle Pines, MN: American Guidance Service.

Kaufman, A. S., & Kaufman, N. L. (2004). *The Kaufman Assessment Battery for Children* (2nd ed.). Circle Pines, MN: American Guidance Service.

Kaufman, A. S., Kaufman, N. L., & Goldsmith, B. Z. (1984). *Kaufman Sequential or Simultaneous (K-SOS)?* Circle Pines, MN: American Guidance Service.

Kaufman, J. C., Kaufman, A. S., Kaufman-Singer, J., & Kaufman, N. L. (2005). The Kaufman Assessment Battery for Children – Second Edition. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 344–370). New York, NY: Guilford Press.

Krechevsky, M. (1991). Project Spectrum: An innovative assessment alternative. *Educational Leadership*, **2**, 43–48.

Krechevsky, M. (1998). *Project Spectrum preschool assessment handbook*. New York, NY: Teachers College Press.

Levy, S. (Ed.). (1994). *Louis Guttman on theory and methodology: Selected writings*. Aldershot, UK: Dartmouth.

Lezak, M. D., Howieson, D. B., & Loring, D. W. (2004). *Neuropsychological assessment* (4th ed.). New York, NY: Oxford University Press.

Lichtenberger, E. O., & Kaufman, A. S. (2009). *Essentials of WAIS-IV assessment*. Hoboken, NJ: Wiley.

Luria, A. R. (1966). *Human brain and psychological processes*. New York, NY: Harper & Row.

Luria, A. R. (1973). *The working brain*. New York, NY: Basic Books.

Luria, A. R. (1980). *Higher cortical functions in man* (2nd ed.). New York, NY: Basic Books.

McDermott, P. A., Fantuzzo, J. W., & Glutting, J. J. (1990). Just say no to subtest analysis: A critique on Wechsler theory and practice. *Journal of Psychoeducational Assessment*, *8*, 290–302.

McGrew, K. S. (1997). Analysis of the major intelligence batteries according to a proposed comprehensive Gf-Gc framework. In D. P. Flanagan, J. L. Genshaft, & P. L. Harrison (Eds.), *Contemporary intellectual assessment* (pp. 151–179). New York: Guilford Press.

McGrew, K. S. (2005). The Cattell-Horn-Carroll theory of cognitive abilities. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 136–181). New York, NY: Guilford Press.

McGrew, K. S., & Flanagan, D. P. (1998). *The intelligence test desk reference (ITDR): Gf-Gc Cross-Battery Assessment*. Boston, MA: Allyn & Bacon.

McGrew, K. S., & Woodcock, R. W. (2001). Technical manual. *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

McKusick, V. A. (1969). On lumpers and splitters, or the nosology of genetic disease. *Perspectives in Biology and Medicine*, **12**(2), 298–312.

McNamee, G., & Chen, J. Q. (2004, August). *Assessing diverse cognitive abilities in young children's learning*. Paper presented at the 27th International Congress of the International Association for Cross-Cultural Psychology, Xi'an, China.

Meeker, M. N. (1969). *The structure of intellect: Its interpretation and uses*. Columbus, OH: Merrill.

Miller, D. C. (2007). *Essentials of neuropsychological assessment*. Hoboken, NJ: Wiley.

Miller, D. C. (Ed.). (2010). *Best practices in school neuropsychology*. Hoboken, NJ: Wiley.

Naglieri, J. A. (2005). The cognitive assessment system. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 441–460). New York, NY: Guilford Press.

Naglieri, J. A., & Das, J. P. (1997). *Das-Naglieri Cognitive Assessment System*. Itasca, IL: Riverside Publishing.

Naglieri, J. A., & Das, J. P. (2002). Practical implications of general intelligence and PASS cognitive processes. In R. J. Sternberg & E. L. Grigorenko (Eds.), *The general factor of intelligence: How general is it?* (pp. 855–884). New York, NY: Erlbaum.

Naglieri, J. A., & Das, J. P. (2005). Planning, attention, simultaneous, successive (PASS) theory. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 120–135). New York, NY: Guilford Press.

Naglieri, J. A., & Johnson, D. (2000). Effectiveness of a cognitive strategy intervention to improve math calculation based on the PASS theory. *Journal of Learning Disabilities*, **33**, 591–597.

Oakland, T., Glutting, J., & Watkins, M. W. (2005). Assessment of test behaviors with the WISC-IV. In A. Prifitera, D. H. Saklofske, & L. G. Weiss (Eds.), *WISC-IV clinical use and interpretation: Scientist-practitioner perspectives*. Burlington, MA: Elsevier Academic Press.

Ortiz, S. O., & Flanagan, D. P. (2002a). Cross-Battery Assessment revisited: Some cautions concerning "Some Cautions" (Part I). *Communiqué*, **30**(7), 32–34.

Ortiz, S. O., & Flanagan, D. P. (2002b). Cross-Battery Assessment revisited: Some cautions concerning "Some Cautions" (Part II). *Communiqué*, **30**(8), 36–38.

Prokosch, M. D., Yeo, R. A., & Miller, G. F. (2005). Intelligence tests with higher *g*-loadings show higher correlations with body symmetry: Evidence for a general fitness factor mediated by developmental stability. *Intelligence*, **33**, 203–213.

Rapaport, D., Gill, M., & Schafer, R. (1945–1946). *Diagnostic psychological testing* (2 vols.). Chicago, IL: Year Book Medical.

Rath, L. K. (2001). Phonemic awareness: Segmenting and blending the sounds of language. In S. Brody (Ed.), *Teaching reading: Language, letters, and thought* (2nd ed.). Milford, NH: LARC Publishing.

Reynolds, C. R., & Kamphaus, R. W. (2003). *Reynolds Intellectual Assessment Scales*. Lutz, FL: Psychological Assessment Resources.

Roid, G. H. (2003). *Stanford-Binet Intelligence Scales* (5th ed.). Itasca, IL: Riverside Publishing.

Roid, G. H., & Miller, L. J. (1997). *Leiter International Performance Scale – Revised*. Wood Dale, IL: Stoelting.

Ruzgis, P. (1994). Thurstone, L. L. (1887–1955). In R. J. Sternberg (Ed.), *Encyclopedia of human intelligence* (pp. 1081–1084). New York, NY: Macmillan.

Sattler, J. M. (2008). *Assessment of children: Cognitive foundations* (5th ed.) San Diego, CA: Jerome M. Sattler.

Sacks, O. (1970). *The man who mistook his wife for a hat and other clinical tales*. New York, NY: Simon & Schuster. Paperback edition Harper & Row (Perennial Library), 1987.

Sauerwein, H. C., & Lassonde, M. (1997). Neuropsychological alterations after split-brain surgery. *Journal of Neurosurgical Sciences*, ***41***(1), 59–66.

Silventoinen, K., Posthuma, D., van Beijsterveldt, T., Bartels, M., & Boomsma, D. I. (2006). Genetic contributions to the association between height and intelligence: Evidence from Dutch twin data from childhood to middle age. *Genes, Brain & Behavior*, **5**(8), 585–595.

Silverman, L. K. (2000). Identifying visual-spatial and auditory-sequential learners: A validation study. In N. Colangelo & S. G. Assouline (Eds.), *Talent development V: Proceedings from the 2000 Henry B. and Jocelyn Wallace National Research Symposium on Talent Development*. Scottsdale, AZ: Gifted Psychology Press.

Spearman, C. (1904). "General intelligence," objectively determined and measured. *American Journal of Psychology*, **15**, 201–293.

Spearman, C. (1927). *The abilities of man: Their nature and measurement*. New York, NY: Macmillan.

Springer, S. P., & Deutsch, G. (1993) *Left brain, right brain* (4th ed.). San Francisco, CA: Freeman.

Stanovich, K. E. (2009). *What intelligence tests miss: The psychology of rational thought*. New Haven, CT: Yale University Press.

Sternberg, R. J. (1982). Reasoning, problem solving, and intelligence. In R. J. Sternberg (Ed.), *Handbook of human intelligence* (pp. 225–307). New York, NY: Cambridge University Press.

Sternberg, R. J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York, NY: Cambridge University Press.

Sternberg, R. J. (1991). Death, taxes, and bad intelligence tests. *Intelligence*, **15**, 257–270.

Sternberg, R. J. (1993). *Sternberg Triarchic Abilities Test*. Unpublished test.

Sternberg, R. J. (1997). *Successful intelligence*. New York, NY: Plume.

Sternberg, R. J. (1999). The theory of successful intelligence. *Review of General Psychology*, **3**, 292–316.

Sternberg, R. J. (Ed.). (2000). *Handbook of intelligence*. Cambridge, UK: Cambridge University Press.

Sternberg, R. J. (2002). *Why smart people can be so stupid*. New Haven, CT: Yale University Press.

Sternberg, R. J. (2003). Construct validity of the theory of successful intelligence. In R. J. Sternberg, J. Lautrey, & T. I. Lubart (Eds.), *Models of intelligence: International perspectives* (pp. 55–80). Washington, DC: American Psychological Association.

Sternberg, R. J. (2005). *The triarchic theory of successful intelligence*. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 103–119). New York, NY: Guilford Press.

Sternberg, R. J., & Clinkenbeard, P. R. (1995). A triarchic model applied to identifying, teaching, and assessing gifted children. *Roeper Review*, **17**(4), 255–260.

Sternberg, R. J., & Detterman D. K. (1986). *What is intelligence? Contemporary viewpoints on its nature and definition*. Norwood, NJ: Ablex.

Sternberg, R. J., Ferrari, M., Clinkenbeard, P. R., & Grigorenko, E. L. (1996). Identification, instruction, and assessment of gifted children: A construct validation of a triarchic model. *Gifted Child Quarterly*, **40**, 129–137.

Sternberg, R. J., & Kaufman, J. C. (1998). Human abilities. *Annual Review of Psychology*, **49**, 1134–1139.

Sternberg, R. J., & the Rainbow Project Collaborators. (2006). The Rainbow Project: Enhancing the SAT through assessments of analytical, practical, and creative skills. *Intelligence*, **34**, 321–350.

Terman, L. M. (1916). *The measurement of intelligence*. Boston, MA: Houghton Mifflin.

Thomson, G. A. (1916). A hierarchy without a general factor. *British Journal of Psychology*, *8*, 271–281.

Thorndike, E. L. (1927). *The measurement of intelligence*. New York, NY: Bureau of Publications, Teachers College, Columbia University.

Thorndike, R. L. (1963). Some methodological issues in the study of creativity. In *Proceedings of the 1962 invitational conference on testing problems*. Princeton, NJ: Educational Testing Service.

Thurstone, L. L. (1936). The factorial isolation of primary abilities. *Psychometrika*, **1**, 175–182.

Thurstone, L. L. (1938). *Primary mental abilities*. Chicago, IL: University of Chicago Press.

Vernon, P. E. (1950). *The structure of human abilities*. London, UK: Methuen.

Vernon, P. E. (1979). *Intelligence: Heredity and environment*. San Francisco, CA: Freeman.

Wasserman, J. D., & Tulsky, D. S. (2005). A history of intelligence assessment. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 3–22). New York, NY: Guilford Press.

Watkins, M. W., Glutting, J., & Youngstrom. E. (2002). Cross-battery cognitive assessment: Still concerned. *Communiqué*, **31**(2), 42–44.

Watkins, M. W., Glutting, J. J., & Youngstrom, E. A. (2005). Issues in subtest profile analysis. In D. P. Flanagan & P. L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests and issues* (2nd ed., pp. 251–268). New York, NY: Guilford Press.

Watkins, M. W., Youngstrom, E. A., & Glutting, J. J. (2002). Some cautions regarding Cross-Battery Assessment. *Communiqué*, **30**(5), 16–20.

Wechsler, D. (1926). On the influence of education on intelligence as measured by the Binet-Simon tests. *Journal of Educational Psychology*, **17**, 248–257.

Wechsler, D. (1939). *The measurement of adult intelligence*. Baltimore, MD: Williams & Wilkins.

Wechsler, D. (1943). Nonintellective factors in general intelligence. *Journal of Abnormal and Social Psychology*, **38**, 101–103.

Wechsler, D. (1949). *Wechsler Intelligence Scale for Children*. New York, NY: Psychological Corporation.

Wechsler, D. (1950). Cognitive, conative, and non-intellective intelligence. *American Psychologist*, **5**, 78–83

Wechsler, D. (1958). *The measurement and appraisal of adult intelligence*. Baltimore, MD: Williams & Wilkins.

Wechsler, D. (2002). *Wechsler Preschool and Primary Scale of Intelligence Scale – Third Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children – Fourth Edition*. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2008). *Wechsler Adult Intelligence Scale – Fourth Edition*. San Antonio, TX: Psychological Corporation.

Woodcock, R. W. (1990). Theoretical foundations of the WJ-R measures of cognitive ability. *Journal of Psychoeducational Assessment*, *8*, 231–258.

Woodcock, R. W., & Johnson, M. B. (1977). *Woodcock-Johnson Psycho-Educational Battery*. Chicago, IL: Riverside Publishing.

Woodcock, R. W., & Johnson, M. B. (1989). *Woodcock-Johnson Psycho-Educational Battery-Revised*. Chicago IL: Riverside Publishing.

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

Woodcock, R. W., & Mather, N. (1989). WJ-R Tests of Cognitive Ability – Standard and Supplemental Batteries: Examiner's manual. In R. W. Woodcock & M. B. Johnson, *Woodcock-Johnson Psychoeducational Battery-Revised*. Chicago, IL: Riverside Publishing.

Zimmerman, I. L., & Woo-Sam, J. M. (1973). *Clinical interpretation of the Wechsler Adult Intelligence Scale*. New York, NY: Grune & Stratton.