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Individual Differences and Cultural and Contextual Factors

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Volume 2: Individual Differences and Cultural and Contextual Factors

CHAPTER 2

FROM GENERAL INTELLIGENCE TO MULTIPLE INTELLIGENCES: MEANINGS, MODELS, AND MEASURES

Richard D. Roberts and Anastasiya A. Lipnevich

Concern for the topics covered in this chapter—intelligence and intelligence testing—has conceivably occupied more space in journals, books, magazines, and websites than any other two related concepts studied in psychology and education over the past century. Our charge, to review models and a selection of measures, is daunting. We have focused on what is largely a consensual model of human cognitive abilities, which appears consistent with many hundreds of empirical studies and covers the most widely used psychometric tests in the field that match this model. We trust that the chapter will challenge readers to question previous assumptions that they might have had about intelligence and intelligence testing and perhaps even give them some ideas for formulating a compelling research or policy agenda.

To achieve these various goals, the chapter is structured in the following way. First, we examine definitional issues that have plagued the field from its inception. Next, we discuss various psychometric models that have been proposed to account for data that have been collected over the course of a century of intelligence testing. This review culminates in a discussion of fluid and crystallized intelligence (Gf–Gc) theory (and the closely related Cattell–Horn–Carroll [CHC] model [McGrew, 2005]) and its various components. Using these models, we then examine several other widely held theories about the concept of intelligence, most notably Gardner's (1983) multiple intelligences framework and Sternberg's (1985) triarchic theory. We then move to discuss a selection of exemplary measures that are entirely consistent with the Gf–Gc and CHC models. We conclude with a discussion of pivotal issues that are likely to guide future research and practice around the topics of intelligence and intelligence testing.

DEFINING INTELLIGENCE

The concept of intelligence, like that of much specialist terminology used in the social sciences, means something far more precise than the way in which the term might be used by the average person on the street. Unfortunately, although scientific concepts should remain free of social values, intelligence is something that remains prized in, and highly intriguing to, almost all cultures. As testament to this claim, consider that more than 48 television channels across the globe regularly host one form or another of "Test the Nation" or "Are You Smarter Than a Fifth Grader?" and that these shows are regularly viewed by many millions of people. Or that a number of cottage industries, which claim to be capable of boosting users' IQs using diverse media, methods, and measures, bring in many millions of dollars each year. How can a specialist term be given to such value-laden connotations? Although dictionary definitions might do injustice to the technical distinctions that the specialist wishes to make, they nonetheless provide clues as to the source of this concept's valence.

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The myriad available online dictionaries variously define *intelligence* as "the capacity to acquire and apply knowledge" (Dictionary.com, 2011), "the ability to learn or understand or to deal with new or trying situations" (Merriam-Webster.com, 2011), and "understanding; intellect; mind" (Barnhart, 1974, p. 1088). In contemporary culture, in which knowledge often equates with status, to be labeled intelligent thus appears highly desirable. Educators, psychologists, policymakers, and other social scientists have arguably found it difficult to escape popular notions once they invoke terminology such as "IQ," "cognitive test performance," "intellect," or "general mental ability." All too often the results from studies in the social sciences are used to encourage views in which the central premise is that the possession of high intellect (i.e., general intelligence) is a necessary condition for life success (e.g., Herrnstein & Murray, 1994).

Allowing that popular notions of intelligence are too subjective, is it possible to find in the psychological or educational literature a meaning that stands up to empirical scrutiny, philosophical scrutiny, or both? From several conferences, spanning nearly a century of research and attended by luminaries from many fields (e.g., Kyllonen, Roberts, & Stankov, 2008; Sternberg & Berg, 1986; Sternberg & Detterman, 1986; Thorndike et al., 1921), it appears that more controversy than consensus exists. One possible reason for this unusual state of affairs may be that few social scientists have attempted to understand the nature of human intelligence, yet many have wanted to join in the discourse surrounding it. The possibility has been expressed that psychologists, educators, and policymakers are "more interested in finding large correlations and making practical predictions with their IQ tests than in advancing our scientific understanding of intelligence itself" (Jensen, 1980, p. 688).

An examination of various definitions of *intelligence* offered by luminaries working in this field illustrates its ineffable character. For instance, Boring (1923, p. 35) defined *intelligence* as "what intelligence tests test," whereas Spearman (1923, 1927) took it to be "the eduction of relations and correlates." P. E. Vernon (1950), by contrast, believed that intelligence equates with "all-round thinking capacity" and "mental efficiency." Wechsler (1944), who developed one of the most popular psychometric measures of intelligence (which we cover later in this chapter), defined the concept as "the aggregate or global capacity of the individual to think rationally, to act purposefully, and to deal effectively with his/her environment" (p. 3).

Each of these definitions, as well as several others offered as alternatives, contains flaws. For instance, in Spearman's (1927) account, it would appear unsound to presuppose the existence of some force that lies behind or explains behavior (Ryle, 1949). The operational definition is also unsound because it begs the question "What is an intelligence test?" In Wechsler's (1974) account, the criteria only obscure a precise conceptualization of intelligence. The meaning of "to act purposefully" or "to think rationally" varies as a function of the individual, situation, culture, or all of these.

INTELLIGENCE AND DEFINITIONAL CONTROVERSIES

In light of this problem of definition, several commentators have argued that the concept of intelligence should be rendered obsolete (e.g., Ceci, 1990; Ceci & Liker, 1986, 1988; Howe, 1990a, 1990b). In perhaps the most acerbic of these critiques, Howe (1990a, 1990b) argued that intelligence is a word that may be used to describe certain classes of behavior but that it fails to explain behavior. For Howe, intelligence serves no more than two descriptive functions. First, *intelligence* exists as a label that identifies a subset of psychological capacities that help an organism to adapt to its environment. Second, it is a term that indicates how well a person deals with certain classes of problems that require cognitive effort. According to Howe, when used as an explanatory construct, *intelligence* is either reified or misused, relying on a linguistic sleight-of-hand whereby the descriptive function that the term serves comes to form the basis of explanation.

Although a critique of Howe's (1990a, 1990b) arguments is outside the scope of this chapter (see, however, Nettelbeck, 1990), his criticisms concerning the empirical status of intelligence clearly rest on the assumption of a single, general factor. This factor, known as *psychometric* g (see e.g., Spearman, 1904), which we review later in this chapter, nonetheless has a status that, in and of itself, is largely questionable. Whether many of the empirical problems Howe raised apply equally well, if at all, to a multidimensional model of human cognitive abilities is doubtful.

Ceci (1990) has made similar criticisms surrounding the concept of intelligence, often with the support of systematic empirical data. For example, Ceci and Liker (1986, 1988) have demonstrated that a group of highly successful gamblers used amazingly complex algorithms, indeed, ones that doctorate-level mathematicians might struggle to develop. One might expect these individuals to have high IQs, and yet their measured general intelligence was in the average range. Without going into details, the arguments subsequently put forward by Ceci (1990; Ceci & Liker, 1986, 1988) downplaying the importance of intelligence contain logical problems (see, e.g., Brody, 1992; Flynn, 1999). Most important, we would argue that Ceci's and his collaborators' arguments are rendered less convincing by the proposition that intelligence is a multifaceted entity.

INTELLIGENCE AS PROTOTYPE AND IMPLICIT THEORIES

Neisser (1979) offered an alternative to dealing with the lack of consensus surrounding the meaning of the concept of intelligence. Using principles derived from cognitive psychology, he asserted that an individual's intelligence is mainly a function of his or her resemblance to a prototypically intelligent person. According to Neisser, no single definition of intelligence is adequate because no single characteristic can adequately define the prototype. Although this work challenges traditional attempts at defining intelligence, it is also possible to reinterpret Neisser's ideas as supporting a view whereby intelligence is perceived as something that is multidimensional.

Using research on prototypes as a basis, Sternberg, Conway, Ketron, and Bernstein (1981) obtained a list of behaviors judged by people in the United States as "ideally intelligent," which these authors then factor analyzed. Ideally intelligent behaviors were found to fall into three distinct classes: problem-solving ability, verbal ability, and social intelligence–competence. In another study conducted with Taiwanese Chinese, five distinct classes were isolated: problem-solving ability, interpersonal intelligence, intrapersonal intelligence, intellectual self-promotion, and intellectual self-effacement (the latter two constructs likely representing personality-related facets of intelligence; Yang & Sternberg, 1997). In short, using data obtained from listing prototypes, there is no evidence for sets of independent factors corresponding to each individual's notion of intelligence nor is there compelling evidence for a single general construct of intelligence.

The preceding review of rather distinctive research traditions suggests that the notion of intelligence being a single unified entity is likely false. The available empirical evidence (to be examined shortly) has largely supported the view that intelligence is composed of several broad factors of ability (e.g., Carroll, 1993; McGrew, 2005). If this is the case, intelligence has been inadequately defined because there are, in fact, not one but several different "types" of abilities. Because empirical data have suggested that these cognitive abilities are relatively structurally independent of one another, each appears to require its own unique conceptualization.

MODELS OF INTELLIGENCE

In the sections that follow, we review a number of intelligence models. We organize them into three broad categories: structural, hierarchical, and systems-level approaches to intelligence. Our selection is not exhaustive and does not include every model discussed in the literature. The models reported herein were chosen on the basis of which scholar's work was most frequently cited in the professional literature and whether the author or his of her contemporaries reported evidence of empirical support. The definitional issues touched on in the preceding passages have clear implications for an important aim of this chapter. In the search for an efficacious model of intelligence, a crucial prerequisite would appear to be the formulation and establishment of several different types of abilities in any given theory.

Structural Theories of Intelligence

Spearman's theory of psychometric g. Perhaps the most famous intelligence theory is that put forward by Spearman (e.g., 1904, 1923). His model states that two factors underlie cognitive test performance: a general factor (g) and specific factors. Specific factors are unique to performance on any cognitive test, whereas the general factor permeates performance on all intellectual tasks. For this reason, Spearman postulated that g alone is of psychological significance. In this model, individual differences in g are the result of differences in the magnitude of mental energy invested in any given task. Spearman believed that the ability to identify associations or patterns among related objects and ideas was largely hereditary.

Equivocal nature of Spearman's theory of g. Support for Spearman's (1904, 1923) theory is thought to occur whenever there is a consistent positive correlation (i.e., positive manifold) among cognitive test intercorrelations and a large first principal component extracted using the technique of factor analysis. However, different collections of cognitive tests may yield different principal components because no one test provides a representative sample of the known cognitive abilities that might legitimately circumscribe the domain of human intelligence (e.g., Horn, 1985, 2008). There can be no psychologically meaningful psychometric g because this varies from occasion to occasion depending on the arbitrary collection of cognitive tests included in a study's design (e.g., Humphreys, 1979; Thomson, 1939/1948). In addition, studies designed as specific tests of Spearman's theory often cannot account for differences in human intellectual capacity (see, e.g., McArdle & Horn, 1983; Rimoldi, 1948; cf. Carroll, 2003). In short, the confusion generated by these varying conceptualizations of the g construct seems difficult to reconcile with its reputed sound, scientific status.

Contemporary models of psychometric g. Despite the lack of empirical data supporting Spearman's g, features of this theory are endorsed in several more contemporary accounts of intelligence (e.g., Belmont, Butterfield, & Ferretti, 1982; Jensen, 1992a, 1998). Often, however, the terminology has been replaced with concepts such as executive functioning (Belmont et al., 1982; van der Sluis, de Jong, & van der Leij, 2007), working memory (Colom et al., 2008; Kyllonen, 1996; cf. Ackerman, Beier, & Boyle, 2005), mental speed (see Stankov & Roberts, 1997), and the like. Such constructs have been argued to assume that a unitary process circumscribes performance on all cognitive tasks (Detterman, 1982). In turn, individual differences are responsible for manifest differences in this process.

Jensen and collaborators (e.g., Jensen, 1987, 1992a; Jensen & Weng, 1994) have made a particularly thorough attempt to preserve the psychometric g framework. These researchers have retained much of Spearman's terminology and the spirit of his research proposals. Jensen (e.g., 1980, 1987, 1992a) provided several reasons for moving to posit a new theory of general intelligence. These arguments have been systematized in a book (Jensen, 1998), an edited volume (Nyborg, 2003), and numerous research articles. Some of the more crucial arguments presented by Jensen include the following.

1. *Existence of positive manifold.* A particularly robust finding in differential psychology acknowledges that intelligence tests correlate in a lawful fashion: "The fact that, in large unrestricted samples of the population, the correlations are virtually always *positive*" means "that the tests all measure some common source of variance in addition to whatever else they may measure" (Jensen & Weng, 1994, p. 232).
2. *Stability of* g *across test batteries.* Jensen (e.g., 1998) claimed that however g is extracted using factor analysis, the coefficient of congruence (a measure of how similar constructs are) between factor solutions remains high.
3. *Practical utility of* g *in the real world is great.* Jensen (1998) argued that psychometric g is the chief active ingredient responsible for cognitive tasks having both practical and concurrent validity in real-life applications. There is some meta-analytic support for this position: Measures of general mental ability are one of the best predictors of workplace performance (Schmidt & Hunter, 1998), although this may simply be

because procedures for classifying tests according to other potential models have not been particularly principled.

4. *Psychometric* g *has meaningful (yet independent) empirical correlates.* According to Jensen (1992a), one of the major features of g is that it correlates with variables that have nothing to do with any statistical methodology, such as factor analysis. Behavioral variables identified by Jensen include decision time, inspection time, and musical tests. In addition, Jensen (1992a, 1998) highlighted that heritability coefficients, inbreeding depression, average evoked potential and the speed of neural transmission, head and brain size, and related constructs also correlate with g.

Critical appraisal of contemporary approaches to g. Jensen's (1992a, 1998, 2002) assertions concerning general mental ability are more equivocal than he would have readers believe. Although a comprehensive critique of Jensen's perspective on the g factor is outside the scope of this chapter, it is difficult to reconcile Jensen's alleged key points with empirical findings in the research literature. Consider, for example, each of the following:

1. *The so-called lawful principles underlying* g *are problematic.* Guttman (1992) provided a disputatious critique of Jensen's (1992a) attempts to apply Spearman's principles (Roskam & Ellis, 1992). In this article, Guttman provided compelling evidence that suggests that both positive manifold and the invariance of g are questionable. Indeed, positive manifold need not mathematically imply the existence of a g factor. Moreover, a large number of noncognitive variables (e.g., athleticism, absence of neuroticism and psychosis, openness, life satisfaction) each correlate positively with intelligence tests yet do not represent a functional unity (Roberts, Pallier, & Goff, 1999).
2. *The general factor does not account for much variance in a test battery.* As Carroll (1995) argued, the first principal component may, at best, account for no more than 50% of the common factor variance observed in cognitive test performance, a figure that appears to represent an upper limit. Whether this figure is construed as satisfactory would seem largely arbitrary. Even so, a substantial percentage of variance—which is neither specific nor error variance—remains unaccounted for in the presence of a general factor (see, e.g., Carroll, 1993; Gustafsson, 1992a, 1992b; Roberts et al., 1999).
3. *The empirical correlates of* g *are problematic.* Almost all of the correlates of g have been questioned. For example, inspection time research has been criticized on methodological, conceptual, and theoretical grounds (e.g., Levy, 1992; Stankov, Boyle, & Cattell, 1995). Similarly, Stankov and Roberts (1997) have questioned the pivotal assumptions under which decision time per se has been linked to general intelligence, supporting these propositions with data (Roberts & Stankov, 1999). These authors showed that measures of mental speed correlate meaningfully with only a subset of cognitive tests—a proposition that is immediately at odds with the concept of a single, general intelligence. With regard to the genetic correlates of g postulated by Jensen (1992b), different perspectives have been offered in the literature (e.g., Carroll, 1993; Cattell, 1971). Similarly, correlations among a variety of physiological variables (e.g., head size) and g seldom exceed .30 (e.g., Jensen & Sinha, 1993), and even this modest correlation may represent an upper limit. Collectively, whether these constructs relate meaningfully to individual differences in intelligence remains equivocal (e.g., Schermer & Vernon, 2010; Stankov et al., 1995; cf. Prokosch, Yeo, & Miller, 2005).

Thurstone's model of primary mental abilities. One of the major differentiating features of structural models of intelligence is the number of factors considered necessary to provide an understanding of intelligent behavior. In a significant departure from Spearman, Thurstone (1931, 1938; Thurstone & Thurstone, 1941) proposed and later verified that certain primary mental abilities exist that collectively make up intelligence. In total, these abilities are thought to replace the notion of psychometric g. Although Thurstone (1938) originally found 13 such factors, he eventually settled on nine that he was able to both consistently validate and assign psychological meaning to. The factors so derived include Verbal Comprehension, Verbal Fluency, Number Facility, Spatial Visualization, Memory, Inductive Reasoning, Deductive Reasoning, Practical Problem Reasoning, and Perceptual Speed. These factors are not ordered in any particular way and are thus of equal importance in detailing the structure of intelligent behavior. For this reason, Thurstone's model is sometimes referred to as an *oligarchic theory.*

Since Thurstone's initial formulations, at least 40 primary mental abilities have been identified (and replicated) in the literature. Carroll (1993, p. 626) suggested that there are somewhere between 65 and 69 primary mental abilities from his reanalysis of 477 datasets. Even this figure is not conclusive. For example, since Carroll's seminal work, additional primary factors have been found for tactile–kinesthesia (e.g., Roberts, Stankov, Pallier, & Dolph, 1997), olfaction (Danthiir, Roberts, Pallier, & Stankov, 2001), processing speed (e.g., Danthiir, Wilhelm, Schulze, & Roberts, 2005), and visual imagery (Burton & Fogarty, 2003).

On these grounds alone, Thurstone's (1938) original theory seems overly simplistic. Equally, it appears extremely difficult to envisage how all of these abilities might form an internally consistent, coherent, and empirically founded theory of intelligence (Horn & Hofer, 1992). In fact, it would be difficult to construct studies that adequately take into account each of these abilities. As a consequence, theoreticians have advocated moving up the ladder of abstraction from a model postulating primary mental abilities to a theory incorporating second-order factors (e.g., Carroll, 1993, 2003; Cattell, 1941, 1971; Horn, 2008). In such theories, primary mental abilities represent components of broader, more meaningful constituents of intelligent behavior.

In this context, even Thurstone (1947) was forced to acknowledge the existence of factors beyond primary mental abilities. This reconceptualization was largely forced by the observation that some primary mental abilities share substantial correlation with one another (see Carroll, 1993). Recent analyses of large datasets, using both exploratory and confirmatory factor analytic techniques (e.g., Carroll, 1989, 1993, 2003; Roberts et al., 2000; Taub & McGrew, 2004; Tirre & Field, 2002), have supported the existence of cognitive factors broader than primary mental abilities.

Structure-of-intellect model. Although the number of factors in Thurstone's (1938) theory is large, Guilford (1967, 1988) took a more extreme view in positing that some 150 (and in some writings 180) factors make up intelligence. In Guilford's (1988) model, every mental task involves three aspects (also called facets): operation, content, and product.

An early appeal of this model was its ability to incorporate both divergent thinking (i.e., creativity) and behavioral cognition (i.e., social intelligence; see O'Sullivan, Guilford, & deMille, 1965) into its structure. Unfortunately, Guilford's (1967, 1988) model has subsequently been criticized extensively. Problems include his use of controversial statistical analyses, failure of independent researchers to recover his factors, and the finding that many of the instruments he developed as tests of the model had questionable psychometric properties. Even so, elements of Guilford's thinking have been modified by several research groups in recent years. For example, an extensive revision of Guilford's (1967, 1971, 1988) facet approach appears in the Berlin Intelligence Structure model (e.g., Jäger, Süss, & Beauducel, 1997). Overlaying these ideas with contemporary knowledge from cognitive psychology and advances in psychometrics, proponents of the Berlin Intelligence Structure have found impressive support for three content facets (verbal, numerical, and figural) and four operation facets (processing speed, memory, creativity, and processing capacity; see, e.g., Beauducel, Brocke, & Liepmann, 2001; Süss, Oberauer, Wittmann, Wilhelm, & Schulze, 2002).

Hierarchical Theories of Human Cognitive Abilities

In the contemporary literature, the most influential and widely used models of intelligence would appear to involve a hierarchical arrangement of factors (e.g., Cattell, 1971; Cronbach, 1990; Horn, 2008; Vernon, 1950). Such models seem to provide the most promising and parsimonious way to conceptualize human ability (e.g., Marshalek, Lohman,

& Snow, 198; McGrew, 2005, 2009; Messick, 1992; Roberts & Stankov, 1999). They also appear to be best supported by the available evidence from both exploratory and confirmatory factor analyses of large datasets (Carroll, 1988, 1993; Gustafsson, 1999; Roberts et al., 2000; Tirre & Field, 2002).

Often in hierarchical theories, but not always, a general mental ability is posited that accounts for performance on a variety of psychological tasks. Beneath this construct are the all important group factors, the definitions of which vary from theory to theory. Each of these factors may, in turn, be divided into narrower, more sharply focused factors—the previously elucidated primary mental abilities.

Theory of fluid and crystallized ability. In Gf–Gc theory, the structure among primary mental abilities is considered to be enough to define a number of distinct types of intelligence. Although researchers sometimes calculate a higher order factor in this paradigm, this factor is most often considered a means of assessing the general organization of behavior (Horn, 1985). Table 2.1 provides a definition of each higher order construct, along with primary mental abilities, tests, and items that should help give the reader a flavor for the theory. Empirical evidence from several lines of inquiry has supported the distinctions between the factors of this theory. Thus, data have shown the following:

1. *Gf–Gc constructs are replicable across diverse adult populations using factor analysis.* Both exploratory and confirmatory factor analysis support the existence of each of the cognitive ability constructs given in Table 2.1. The ensuing model derives from analysis conducted in no fewer than 20 countries, with data collected since 1925, involving anywhere from six to 100 variables per study, on populations that include university, community college, and K–12 students; military enlistees and officers; gifted individuals; community volunteers; prison inmates; hearing impaired; and many other types of special populations of varying ages (see Carroll, 1993).
2. *Meaningful differential relations with cognitive correlates.* Each of the broad factors has unique underlying cognitive processes and functions associated with it (e.g., Fleischhauer et al., 2010; Horn, 2008; Horn & Hofer, 1992; Roberts & Stankov, 1999; Stankov & Roberts, 1997; Stankov, Roberts, & Spilsbury, 1994). For example, Gf has been tied to a variety of attentional factors (e.g., Stankov, 1988) and Gc has been tied to long-term working memory (e.g., Horn, 2008; Horn & Masunaga, 2000).
3. *Differential test-criterion relations.* Each of the broad factors shares different predictive validities for a number of valued personal and societal outcomes, all along the developmental continuum (e.g., Swanson, 2008), up to and including predicting mortality (e.g., O'Toole & Stankov, 1992).
4. *Differential sensitivity to training and other forms of intervention.* Each broad second-order construct is differentially sensitive to various forms of intervention (e.g., Eilander et al., 2010; Kyllonen et al., 2008; Stankov, 1986), including those based on nutrition and health-related factors (Benton, 2008).
5. *Different learning trajectories, different genetic components.* The various factors making up Gf–Gc theory also appear to be subject to different sets of learning and genetic influences (e.g., Horn, 1985, 1987; Horn & Hofer, 1992; Horn & Noll, 1994), with evidence also suggestive of different physiological mechanisms (e.g., Stankov et al., 2006).

In Gf–Gc theory, each of the factors is deemed structurally equivalent. However, most researchers (largely because of historical precedent) have focused attention on Gf and Gc abilities, which share important common features. For example, both can be measured by speeded or power tests with material that can be presented in any of the three forms: pictorial–spatial, verbal–symbolic, or verbal–semantic. The main distinguishing feature between Gf and Gc, however, is the amount of formal education and acculturation that is present in either the content of or operations required during tests used to measure these abilities. That Gf depends to a much smaller extent on formal education experiences than does Gc is well established (e.g., Horn, 1998, 2008). The available evidence has equally tended to suggest that Gf has greater genetic

TABLE 2.1

Definitions of Major Constructs of Fluid Intelligence–Crystallized Intelligence Theory, Representative Primary Mental Abilities Identified by Carroll (1993), and Sample Tests and Items

Construct	Definition	Primary mental abilities	Sample tests and item
Fluid intelligence	A broad organization of ability concerned with basic processes that depend minimally on learning and acculturation	Sequential reasoning, induction, Piagetian reasoning, speed of reasoning, quantitative reasoning	Induction: What is the next number in this sequence? 1 2 1 4 1 6 1 8 1 Arithmetic reasoning: If six workers are needed to finish building a house in 9 days, how many workers would be needed to finish the house in 2 days?
Crystallized intelligence	Organization of ability reflecting the influences of formal learning and acculturation (including education)	Verbal comprehension, listening ability, phonetic coding, lexical knowledge, reading decoding, reading speed, oral production, writing ability, language development	Vocabulary: What is the meaning of the word *peripatetic*? General knowledge: The author of the book *One Day in the Life of Ivan Denisovich* was ___________?
Memory and learning (also called *short-term acquisition retrieval*)	Organization of ability involved in any task concerning retention of material over a very short period of time	Memory span, associational memory, free recall memory, meaningful memory, visual memory, learning ability	Digit Span: The test administrator presents a series of digits with a 1-second delay between each. The participant recalls the digit string (Stimuli: 3 7 8 4 2 6). The test is also given backwards in which, for example, the correct response is 6 2 4 8 7 3.
Broad visualization	A broad organization of ability involved in any task that requires the perception of visual forms	Visualization, spatial relations, closure speed, flexibility of closure, serial perceptual integration, length estimation, perception of illusions, spatial scanning	Card rotations: Consists of 10 target two-dimensional shapes, each with eight variations. Participants decide whether the variations are reflections of the target or the same shape, marking one of two boxes designating their response as quickly and accurately as possible.
Broad auditory reception	A broad organization of ability involved in any task or performance that requires the perception of, or discrimination of, auditory pattern of sounds or speech	Absolute pitch, temporal tracking, maintaining rhythm, resistance to distortion, sound localization, hearing–speech threshold, sound frequency discrimination, memory for sound patterns, speech sound discrimination	Auditory closure: Words are presented orally but with some sounds omitted. The task is to complete the word. Stimuli: bo/le [bottle]
Retrieval ability (also known as *tertiary storage and retrieval*)	A broad organization of ability involved in any task involving retention of material learned in the distant past	Originality, ideational fluency, figural fluency, expressional fluency, word problems, naming facility, associational fluency, figural flexibility	Ideational fluency: In 2 minutes list the members of a broadly defined class, with the score being the number of things listed (e.g., animal names beginning with the letter *d*).

TABLE 2.1 (*Continued*)

Definitions of Major Constructs of Fluid Intelligence–Crystallized Intelligence Theory, Representative Primary Mental Abilities Identified by Carroll (1993), and Sample Tests and Items

Construct	Definition	Primary mental abilities	Sample tests and item
Broad cognitive speed	A broad organization of ability in any task or performance that requires rapid cognitive processing of information	Rate of test taking, numerical facility, perceptual speed	Letter comparison: Indicate whether the two letter strings are the same or different (note time, rather than accuracy, is the dependant variable): BFYTRZXVH–BFYLRZXVH
Broad decision speed	A broad organization of ability in task or performance that requires rapid processing of very simple stimuli	Simple reaction time, choice reaction time, mental comparison time, semantic processing speed	Card-sorting: Sort a deck of playing cards into colors, suits, or number Posner task: Indicate whether two letters have the same meaning (e.g., Aa; yes) or are physically the same (e.g., Aa; no)

concomitants than does Gc, although it is not conclusive (see e.g., Horn & Hofer, 1992; Horn & Noll, 1994).

Gf and Gc also show distinct developmental trends during adulthood. Thus, although Gc remains constant or shows slight increment over the course of an individual's life span, Gf generally declines as a function of age (see Horn, 1979, 1988; Stankov, 1988). These different developmental trajectories appear to be a function of the proposed information-processing mechanisms underlying the Gf–Gc distinction. Hence, Gf appears dependent on the capacity of working memory (e.g., Kyllonen & Christal, 1990). Gc, in contrast, is thought to depend on long-term memory store and the organization of information within that store (Horn, 2008). Research has suggested that working memory deteriorates with age as a function of neurological decay, whereas long-term store is less prone to such effects. The concerned reader, who might be older than 26 years of age when Gf first begins to decline, should note that the effects are gradual. In any event, the improvement witnessed in the individual's Gc (until very old age, when this too appears to decline) tends to be nature's compensation.

A major instantiation of the utility of Gf–Gc theory comes from the literature on aging in which there has been some controversy regarding the effects of age on intellectual functions. Previously, researchers argued for no decline in intelligence with age (e.g., Baltes, Reese, & Lipsitt, 1980), largely because they assumed a single-factor model of intelligence. This model contradicts an established empirical fact—as one becomes older, scores on verbal tests (e.g., vocabulary) tend to improve, whereas scores on tasks requiring the mental manipulation of letters, objects, or shapes (e.g., Raven's Progressive Matrices Tests) tend to decline. By contrast, Gf–Gc theory predicts this finding. Subsequently, the literature on cognitive aging predominately uses the Gf–Gc model (see, e.g., Fry & Hale, 1996; Salthouse, 2001). Indeed, attempts to account for the cognitive processes underlying developmental trends in separate domains of task performance is currently one of the most lively research topics in the field of gerontology (e.g., Hertzog, Kramer, Wilson, & Lindenberger, 2009; Salthouse, 2001; Wilson et al., 2009).

Cattell–Horn–Carroll model. Despite criticisms we raise throughout this chapter concerning the concept of a general intelligence factor, many practitioners still want to have a single test score reported out when administering a cognitive test. Being responsive to their client's wishes, major test developers thus include this aspect in their test design. Because Carroll (1993) also included a general factor in many of his reanalyses of second-order Gf–Gc factors, these test developers now have an evidentiary base for this market-driven requirement. The ensuing paradigm is often referred to as the CHC model. Although we believe that our case against psychometric g is compelling and that this general factor should be interpreted with a great deal of caution, in the interests of representing others' views in the chapter accurately, we refer to the CHC model rather than Gf–Gc theory in our subsequent review of four major intelligence tests. However, before doing so, let us turn our attention to systems models of intelligence.

System Models of Intelligence

Two contemporary theorists—Howard Gardner and Robert Sternberg—have proposed intelligence models that attempt to be relatively all encompassing in dealing with both the internal and the external world of the human being. Because such theories view intelligence as a complex system, they are often referred to as *system models*, a term that we use to demarcate them from the models covered earlier. Interestingly, such system models, in expanding notions of the proper subject matter of intelligence, include concepts that most other theories of human cognitive abilities, particularly structural models, might not view as intelligence.

Gardner's (1983) multiple intelligences. Gardner (1983) has proposed a theory of multiple intelligences (see also Chen & Gardner, 1997; Gardner, 1993), which begins with the assertion that all contemporary models thus far proposed are restrictive in how they conceptualize human intelligence. This model is not based on factor-analytic evidence but rather on Gardner's (1983) analysis of information derived from a number of sources, including evolutionary psychology, neuropsychology, anthropology, gifted research, philosophy, and clinical psychology. For a candidate concept to qualify as one of the many intelligences of Gardner's model, it must meet inclusion criteria (from among eight possibilities). Because of its intuitive appeal, the theory has attracted considerable attention. The underlying message—that there is more than a single, general factor—immediately found acceptance among educators and applied psychologists who had become increasingly disenchanted with the psychometric g framework. It is interesting that these same groups had apparently not been widely exposed to Gf–Gc theory, perhaps because it has not been widely disseminated in the same manner as Gardner's (1983) seminal contribution.

In all, seven independent types of intelligence are in Gardner's (1983) original theory. Next, we list each type of intelligence, along with a brief description intended to capture salient aspects of each construct. Note that each of the seven intelligences derives from Gardner's subjective classification of individual differences in human performance, using what he believed to be important scientific criteria, ostensibly derived from the armchair.

1. *Linguistic intelligence.* This ability involves sensitivity to spoken and written language, the ability to learn languages, and the capacity to use language to accomplish certain goals. This intelligence includes the ability to effectively use language to express oneself rhetorically or poetically and to use language as a means to remember information. Writers, poets, lawyers, journalists, and orators are among those that are seen as having high linguistic intelligence.
2. *Visual–spatial intelligence.* This ability helps the individual to read a map, to get from one place to another along the shortest route, and to play platform computer games effectively. High levels are evidenced in the great paintings of the world, architectural monuments, engineering feats, and presumably those who post high scores around the globe on various online computer games.
3. *Logical–mathematical intelligence.* This ability is used to solve mathematical problems, to solve complex mathematical proofs, and to perform statistical analyses. High levels ensure success in the science, technology, engineering, and mathematics disciplines.
4. *Musical intelligence.* This ability is evidenced when singing a song, composing a piece of music, or playing a musical instrument. Musical intelligence might also come into play whenever an individual appreciates or can recognize the structure of a particular piece of music. High levels are evidenced in the musical scores of the

great composers, the music played by classical and jazz musicians, and the reviews of the professional music critic.

5. *Bodily–kinesthetic intelligence.* This intelligence is hypothesized to be quite diverse and is demonstrated when one dances or plays any sport. In terms of Gardner's (1983) model and the hypothesized independence of the multiple intelligences, bodily–kinesthetic processes appear to have much in common with visual–spatial intelligence, at least from a psychometric perspective (Roberts et al., 1997; Stankov, Seizova-Cajic, & Roberts, 2001).
6. *Interpersonal intelligence.* This ability is used whenever one relates to other people, such as trying to understand what another person is feeling after he or she has been insulted. Interpersonal intelligence more generically covers the individual's attempts to understand another person's behavior, motives, and emotions.
7. *Intrapersonal intelligence.* This intelligence is used to help people understand themselves. Gardner (1983) assumed that this concept forms the basis for understanding one's place in the world, what makes people tick, and what drives them. Intrapersonal intelligence also informs people how they can change themselves into becoming more fulfilled people given the constraints of their abilities and interests. It is uncertain how this notion might be disentangled for interpersonal intelligence given that high intrapersonal intelligence would appear a necessary and sufficient condition for high levels of interpersonal intelligence (Matthews, Zeidner, & Roberts, 2003).

The original list of seven intelligences was expanded in Gardner's (1999) later writings with the addition of naturalistic intelligence. This construct is defined as the ability to recognize, identify, and classify flora and fauna or other classes of objects. Biologists, zoologists, and professional chefs are those who are thought to display high naturalistic intelligence. On a side note, this intelligence defeated two additional candidates—spiritual and existential intelligences—and was chosen on the basis that it satisfied a larger number of the required criteria for inclusion in the model. Gardner (1983) acknowledged that one can never develop "a single irrefutable and universally acceptable list of human intelligences" (p. 60); hence, he did not limit the final number of intelligences. On what basis, then, a reader might conjecture, did he choose this particular subset of eight intelligences? The answer lies in eight criteria, to which we turn now.

1. *Potential isolation by brain damage.* Accidents can result in lesions in certain parts of the brain or, worse still, lead to the destruction of certain parts of the brain. Studying patients with such damage is an important aspect of neuropsychology. Certain groups of patients can be studied to isolate the portions of the brain that are responsible for particular mental functions. The individual lacking that part of the brain should not be able to perform a cognitive function that is supposedly located in the damaged portion. The aim of such studies is to localize brain functions, and indeed the evidence that some functions are localized is considerable. For example, in normally functioning brains speech and language functions appear to reside in the left cerebral hemisphere, and tasks that call on visual and auditory perceptual abilities are localized in the right hemisphere. On the basis of such findings, Gardner (1983, 1993, 1999) contended that multiple intelligences exist because people have multiple neural modules. The modularity of intelligences, in turn, suggests that a person's ability in one area does not predict his or her ability in another.
2. *Existence of exceptional individuals in the domain of interest.* Idiot savants may perform very poorly on typical tests of intelligence and yet show exceptional capabilities in certain domains. Some of them can reproduce faultless imitations of classical paintings, and others can carry out incredibly involved mathematical calculations in an amazingly short period of time (see, e.g., Mottron, Dawson, Soulières, Hubert, & Burack, 2006). Similarly, prodigies have extraordinary gifts in one area, with normal abilities in all others. Both groups seem to have some rather specific area of cognitive functioning that is highly developed relative to other areas of functioning.

Gardner (1983) believed that these high levels of performance are again indicative of separate, modular intelligence systems.

3. *An identifiable set of core operations.* Gardner (1983) believed that each of the eight intelligences should have its own distinctive set of operations, which may be used in the execution of that intelligence. For example, musical intelligence has as its core operation the ability to discriminate tones according to pitch. Linguistic intelligence, by contrast, is supposed to contain four different core operations, rhetorical ability, memory ability, explanatory abilities, and the ability to understand the meaning conveyed by language. Thus, if one can identify the complete set of operations or some core operation, the case for the existence of that particular type of intelligence is strengthened.
4. *Distinctive developmental history and definable set of expert characteristics.* One way of separating a given intelligence from any other is to show a pattern of development throughout childhood that is distinctive with respect to that intelligence. Some types of intelligence appear to develop gradually, and other types show spurts of development at a particular age. Indeed, Gardner (1983) suggested that the fact that one domain of human capability develops more quickly (or slowly) than another supports the notion of separate multiple intelligences.
5. *Evolutionary plausibility.* The origins of each of the intelligences, according to Gardner (1983, 1993), must go back many millions of years. However, very little is known about their evolutionary history. Nevertheless, the plausibility of a specific intelligence may be enhanced if it can be shown that there are antecedents to its present stage. For example, Gardner (1983) claimed that bird song might be seen as a forerunner of musical intelligence, whereas the use of tools by some animals may be seen as an ancestor of bodily–kinesthetic intelligence.
6. *Support from experimental psychological tasks.* Experimental psychological investigations that point to different patterns of stimuli leading to distinctive reactions in the organism also demonstrate the distinctiveness of the intelligences. For example, manipulations of the properties of visual stimuli lead to changes in performance on spatial tasks, whereas changes in auditory stimuli lead to changes in performance on musical tasks. In turn, these experimental findings suggest that these represent two distinct types of intelligence.
7. *Susceptibility to encoding in a symbol system.* Each of the intelligences should also have its own distinctive, culturally predetermined symbol system. For example, in the case of linguistic intelligence, the symbol system consists of the formal rules of language. Similarly, in musical intelligence, the symbols are musical notes, whereas for logical–mathematical intelligence it is logical or mathematical notations. Gardner's (1983) argument rests here on the assumption that symbol systems have developed because separate intelligences had to have a means of expressing themselves.
8. *Support from psychometric findings.* In addition to all the preceding criteria, Gardner (1983) claimed that patterns of intercorrelations among psychological tests and factor analysis also support the theory of multiple intelligences. To get around some conflicting evidence, Gardner pointed out that the intelligence tests that have been used in education and psychology are based on paper-and-pencil formats of presentation, and therefore some of the important types of intelligence might have been missed.

Gardner's theory: A critique. In Gardner's (1983) view, each of the intelligences must satisfy most, rather than all, of the specified criteria—a rule that strips the process of selection of its scientific rigor. Most of the criteria for inclusion are rather easy to satisfy, so the list of intelligences can be endlessly expanded. At the same time, certain intelligences that appear to meet a majority of the criteria (e.g., those related to memory functions) are excluded from the final list for reasons that Gardner did not explicate. Hence, because the choice of criteria has a large element of subjectivity associated with it, Gardner's theory may be considered an idiosyncratic view, a rhetoric, or a taxonomy of human talents at the very best (for additional critiques, see Brody, 1992; Messick, 1992).

It is perhaps necessary to highlight these criticisms with a few examples. First and foremost, concerning modularity, a major problem with Gardner's (1983) view is that although some abilities are highly localized, performance on most complex tasks cannot be linked to any particular site in the brain. So, according to Gardner's theory, mathematical and spatial reasoning are separate and self-sufficient entities, whereas evidence from neuroscience has suggested otherwise. It appears that Gardner viewed neuroscience as bearing out the assumption that the human mind is a confederation of largely independent, highly compartmentalized processes. Such interpretation is an oversimplification of the current state of knowledge in this field.

Moreover, there are certainly some candidate processes (e.g., olfaction) that should seemingly be added to Gardner's (1983) list. Olfactory intelligence would meet a majority of the specified criteria. It can be used to solve problems, can be isolated by brain damage, and has a distinct developmental history (Danthiir et al., 2001). Furthermore, some individuals show heightened sensitivity and exceptional memory for odors (e.g., Proustian memory). The evolutionary plausibility of this intelligence is easy to defend as well. Olfaction would certainly be adaptive in a social species such as ours. However, olfaction, along with other sensory systems, was excluded from consideration, whereas action systems, such as bodily–kinesthetic, were not. Gardner did not provide a compelling rationale for such decisions.

In addition, how might Gardner's (1983) theory account for the fact that measures of tactile and kinesthetic performance (putative indices of bodily–kinesthetic intelligence) correlate so highly with measures of visualization (i.e., Gardner's visual–spatial intelligence; see Roberts et al., 1997; Stankov et al., 2001)? Indeed, this finding appears to be one that sport psychologists must certainly have preempted, given the suggested benefits of visual imagery to elite athletes. Equally, how would Gardner reconcile the fact that mathematical abilities appear to be structurally independent of measures of logical reasoning (see Horn & Noll, 1994), when they clearly appear to constitute the same construct (i.e., logical–mathematical reasoning) inside his theory?

Indeed, comparisons of Gardner's (1983) theory with structural models leave the reader to ponder both considerable overlap and a number of potentially serious omissions. For example, the first four types of intelligence in Gardner's list have counterparts in contemporary structural models and appear more clearly specified therein than he led his readers to believe. But what of replicated cognitive abilities, which do not have counterparts in Gardner's theory of multiple intelligences? Among primary mental abilities, concepts such as associational fluency, memory span, decision speed, and perceptual speed cannot be easily classified inside Gardner's system, not to mention the fact that higher order memory and mental speed (both of which one could easily mount a compelling rationale for including as a form of multiple intelligence) are not even entertained.

A further limitation of Gardner's (1983) theory concerns the potential proliferation of intelligences. Assuming that bodily–kinesthetic intelligence is a distinct domain, should one also distinguish athletic intelligence, football intelligence, dance intelligence, and golf intelligence? If not, one might assume that an individual who turns out to be highly proficient at football or golf might equally have turned that talent to performing in a classical ballet production. Similarly, the concept of musical intelligence conceals differences between writing a musical score for the symphony and being able to play in a highly successful rock band without any formal training. Indeed, differences have even been documented in people's ability to play various musical instruments (Judd, 1988). It is questionable also whether some of these aptitudes are as important to real life as the cognitive intelligences. Certainly, being unable to appreciate a musical score detracts from the quality of one's life, but low musical or naturalistic intelligence does not disrupt everyday functioning as might low Gf or Gc.

On a concluding note, Gardner's (1983) model has not been widely accepted by the scientific community but has received a strongly positive response from many educational practitioners. A number of schools in North America and Europe have looked to structure curricula according to Gardner's theory and to design entire schools to reflect Gardner's teaching (Brody, 1992; White, 1998). The appeal is obvious: A child who is not good at math or reading but who is musically talented can be referred to as possessing high musical intelligence. Thus, Gardner's theory gives educators and parents the permission to cancel out a deficiency in one area with good performance in another domain. After all, if both are intelligences, both must be equally as important. Hardly any scientific evidence has demonstrated the effectiveness of programs that apply Gardner's principles to teaching (just as there are virtually no data-driven studies supporting Gardner's main theoretical contentions). Therefore, with limited empirical support and a plethora of serious inconsistencies, Gardner's theory should be construed as an educated opinion at the very best.

Sternberg's (1985) triarchic theory. Sternberg (1985) has also emphasized a departure from traditional conceptualizations of intelligence. In particular, he defined intelligence as "purposive adaptation to, and selection and shaping of, real-world environments relevant to one's life" (Sternberg, 1985, p. 45). Using a variety of analogies, Sternberg argued that academic intelligence, as assessed by psychometric tests, is imperfectly related to the ability to function intelligently in everyday life. For example, he gave anecdotal evidence of academically intelligent individuals who do not function well in academic settings because of emotional difficulties. On this basis, he goes beyond IQ to emphasize different aspects of intellectual functioning (Sternberg, 1985).

In its entirety, Sternberg's (1985) triarchic theory of intelligence acknowledges that the term *intelligence* has many meanings. As the name suggests, the theory consists of three parts (also known as *subtheories*)—componential, experiential, and contextual—which are developed in this theory. We highlight these different subtheories, along with subcomponents making up each subtheory, in the passages that follow.

Componential subtheory: Intelligence and the internal world of the individual. This part of triarchic theory refers to states and processes that underlie intelligent thought. Sternberg proposed three components, which essentially represent information-processing mechanisms that appear in theories emanating from cognitive psychology.

1. *Performance components.* Analogy items (e.g., red is to stop as green is to?) include cognitive processes such as inference, mapping, encoding, and so forth. Other types of intelligence test items may have different sets of performance components. A possible criticism of these performance components is the potentially infinite number of these processes. Thus, it is not known which processes are the most important or whether researchers should focus on narrow, atomistic processes or processes that are broader in scope.
2. *Metacomponents.* Metacomponents are higher order executive processes that are used to plan what one is going to do, to monitor the ongoing process, and to evaluate its effects after it is completed. Metacognition, for example, involves recognizing the existence of a problem, selecting a set of appropriate lower order components, choosing a strategy that combines performance components, monitoring solution processes, and evaluating the adequacy of a solution.
3. *Knowledge acquisition components.* Knowledge acquisition components are used to learn how to do what the metacomponents and performance components eventually do. They include sifting relevant from irrelevant information (selective encoding) and combining the selected information to form an integrated and plausible whole (selective combination and comparison). These knowledge acquisition components are important in acquiring an extensive vocabulary.

Experiential subtheory: Intelligence and experience. According to Sternberg (1985), intelligence is best measured by processes involving tasks and situations that are relatively novel or are in the process of becoming highly automatized over time. Thus, two aspects of this subtheory are emphasized.

1. *Ability to deal with novelty.* Intelligent people can solve tasks that have not been attempted previously and are nonentrenched. According to this aspect of triarchic theory, novel tasks make demands on a person's intelligence and are quite different from those tasks in which automatic procedures have been developed. Inside triarchic theory, relatively novel tasks (e.g., learning a new foreign language; becoming familiar with a new computer operating system) demand more of a person's intelligence. Acknowledging the importance of Gf–Gc theory, Sternberg (1985)

also pointed out that novelty is a characteristic of many tests of Gf.

2. *Ability to automatize information processing.* The ability to automatize a particular process has been claimed to be a major aspect of intelligent behavior. The process of reading, for example, can be highly practiced and automatized, as can the process of note taking, debating, and using computer software. Consistent with the notion of positive manifold mentioned earlier in this chapter, it is also the case that more intelligent people are generally faster at each of these activities. Experiments with the acquisition of various skills (e.g., chess playing) show that people who score high on intelligence tests acquire these skills more rapidly than people with lower measured intelligence.

Contextual subtheory: Intelligence and the external world of the individual. The role of environment in intelligence is emphasized in the contextual subtheory, placing Sternberg (1985) in direct opposition to strict proponents of psychometric *g* (e.g., Jensen, 1987, 1992a). Intelligence has been argued to be not an aimless (or random) mental activity that happens to involve certain components of information processing and certain levels of experience. Rather, intelligence may be defined in terms of behaviors that are relevant to one's life. Intelligent behavior has been proposed to be directed toward certain goals and in particular toward the following:

1. *Adaptation to environment.* Intelligence involves adaptation to (i.e., achieving a good fit between oneself and) the environment (cf. Wechsler, 1974). Environments differ, and although the same components may be involved, behavioral manifestations of these processes may differ across cultures. Thus, tests of intelligence that are adequate in one context may not fare so well in another, differentiated context. In addition, entirely diverse abilities may develop in disparate cultures (e.g., spatial abilities among the Eskimos, Australian Aborigines, and Polynesian navigators are quite different).
2. *Shaping of environment.* If adaptation is not possible, intelligent behavior often results in an attempt to shape and change that environment. In many fields of human endeavor (e.g., science, arts, technology), bona fide experts tend to establish new paradigms or trail-blazing approaches; that is, they ostensibly shape their environment. Those who follow them resort to adaptation. The difference, of course, is not in the individual's use of shaping alone but rather rests on a combination of their willingness to shape the environment, along with their skills and capacities to be capable of doing so.
3. *Selection of new environment.* If adaptation and shaping fail, intelligent behavior is often indicated by leaving one environment and choosing another. A typical example is changing jobs or career paths to better suit one's goals, interests, and skill level. There are many examples in which selection of a new environment is the most intelligent course of action. Sternberg (1985) mentioned "the fate of the quiz kids." As children, these individuals were selected for radio and TV shows on the basis of high intellect and desirable personality traits. Almost all of them had exceptionally high IQs, typically well over 140 on standardized measures of intelligence. Their adult lives, however, appear rather devoid of high achievement. Those who did achieve more than the rest appear to have been particularly adroit at finding out what they were good at and pursuing this activity relentlessly. The less successful ones could not find any one thing that interested them.

The main point of Sternberg's (1985) contextual subtheory is that the expressions of intelligence can differ widely across individuals and groups, such that intelligence cannot be understood independently of the ways in which intelligent behavior is manifested. People mastering their environment seem to be able to capitalize on their strengths and compensate for notable weaknesses. According to Sternberg, what is adaptive differs by degree, both across people and across situations; therefore, intelligence is not quite the same thing for different people, different situations, or both.

Triarchic theory: A critique. Sternberg's (1985) triarchic theory represents an ambitious attempt to reconcile psychometric, information-processing, cultural, implicit, and prototypical conceptions of human intelligence. Some notions contained inside his subtheories may, however, be criticized on philosophical grounds, and the central tenets of triarchic theory are sometimes difficult to refute (i.e., they do not appear falsifiable). Indeed, although triarchic theory represents an ambitious attempt to establish a model of intelligence that combines many different aspects of scientific knowledge, extant empirical evidence supporting almost all of the components is scant. Carroll (1980, 1993), for example, has called for Sternberg's data on analogy tasks to be factor analyzed to show the generality of performance components over different tasks. Although it is possible to derive anecdotal evidence for many of these components, empirical studies are scant. We might also question how concepts that are clearly part of the cognitive ability realm and of some importance both conceptually and practically (e.g., broad auditory reception, broad memory factors) might fit inside triarchic theory (Gottfredson, 2003).

A final comment on systems theories. Both Gardner's (1983) and Sternberg's (1985) theories have had some influence in the education and psychology literature, but often as a counterpoint to structural models discussed earlier. It is noteworthy that neither theory has resulted in a major intelligence test that is widely used by any community of practice. Neither have these systems models played a major role in shaping major social, economic, or educational policies. In terms of theoretical soundness, there is arbitrariness to these models, which can quickly be countered by various thought experiments, rendering alternative explanations equally plausible. Indeed, as Sternberg (1996) acknowledged, systems theories are so broad that they have proven difficult to disconfirm: "A sound theory should be specific enough that it could clearly be disproved, if evidence against it were to be found . . . but systems theories are so general that they incorporate almost anything under, say, 'adaptation to the environment'" (p. 396).

ASSESSMENT OF INTELLIGENCE

In this section of the chapter, we present a brief overview of four intelligence tests that are widely used in education and psychology and that have rich research traditions. The review is by no means exhaustive nor are any of the tests wholly representative of psychometric assessment of ability constructs; new and revised tests appear every month, and literally thousands of studies are published every year on intelligence tests that are quite different from the tests covered by this review. However, the four selected tests constitute those that are among the most widely used (especially for school-age respondents), have the longest traditions in both basic and applied research, and serve as standards to which other contemporary tests are often compared (see, e.g., Cohen & Swerdlik, 2009; Kaplan & Saccuzzo, 2008). Readers interested in more expansive coverage of the universe of intelligence tests can find information in (a) *Mental Measurement Yearbook* (e.g., Geisinger, Spies, Carlson, & Plake, 2007), which is published approximately every 3 years (a new edition is forthcoming in 2010); (b) *Encyclopedia of Human Intelligence* (Sternberg, 1994); and (c) many of the textbooks devoted to psychological assessment (e.g., Gregory, 2006; Groth-Marnat, 2009), although all sources can date rather quickly in light of emerging findings, new test forms (or revisions), or both.

The four measures that we would like to bring to readers' attention are the Woodcock–Johnson III (WJ–III) Test of Cognitive Skills, the Wechsler Intelligence Scale for Children—IV (WISC–IV) Integrated, the Stanford-Binet Fifth Edition (SB–V), and the Kaufman Assessment Battery for Children—II (KABC–II). Table 2.2 provides a succinct summary of the main characteristics, including psychometric qualities, theoretical bases, and information about benefits and drawbacks of each of the four assessments. Space precludes detailed consideration of these tests, but we hope that readers will pursue this topic on their own. For now, we would like to highlight a few general points about each of the four measures.

WJ–III

It is our contention that the WJ–III is one test that both researchers and practitioners should consider using more often, although even one of the test authors has acknowledged the need to supplement these tests with other assessments (McGrew &

TABLE 2.2

Summary of Characteristics of Four Exemplary Intelligence Tests

Characteristic	Woodcock–Johnson III Test of Cognitive Skills	Wechsler Intelligence Scale for Children—IV Integrated	Stanford-Binet Fifth Edition	Kaufman Assessment Battery for Children—II
Age	2–90+ years	6–16 years, 11 months	2–85+ years	3–18 years, 11 months
Scores provided	Global cognitive ability score; cluster scale scores; individual test scores	Full scale IQ; verbal comprehension, perceptual reasoning, working memory, and processing speed scale scores	Full scale IQ; verbal and nonverbal intelligence scores; individual scores on each subscale	Varies depending on participants' age
Theoretical basis	CHC theory	CHC theory	Cattell's Gf–Gc theory	CHC theory and Luria's (1966) neuropsychological model
Norming sample	8,818 participants	2,200 children	4,800 participants; ages 2–85+	3,025 children
Sampling procedures	The distribution of data was proportional to the U.S. population distribution, balanced on geographic region, community size, race, gender, type of school, and parents' education	Equal number of males & females in each group; ethnic composition that matches the U.S. Census; five levels of parental education; four geographical areas of United States (and Hawaii)	Normative sample closely matches the 2000 U.S. Census; sample balanced by gender, ethnicity, culture, religion, region, and socioeconomic status	Sample representative of the population of the United States on the basis of age, gender, ethnic group, geographic region, community size, parental education, and educational placement
Reliability evidence	High: .69–.98	High: .67–.91	High: .90–.98	High: .69–.97
Validity evidence	Extensive	Limited	Extensive	Extensive
Pros	Impressive psychometric properties; broad age range; wide applicability (across various ethnic backgrounds, for individuals with disability, and giftedness screening); relative ease of administration and objective scoring	Broad clinical applicability; popular and widely used	Solid experimental support; wide applicability (clinical and neuropsychological assessment; early childhood assessment; psychoeducational evaluations for special education placements; adult social security and workers' compensation evaluations, etc.)	Theoretical soundness; experimental support; applicability to children of limited ability and limited language skills
Cons	Takes a long time to complete; requires individualized administration and a trained examiner; limited use as a diagnostic tool for special education programs	Weak research evidence supporting process components; limited validity evidence; limited information in the manual supporting the validity and interpretation of test scores	Many broad abilities of plausibly important significance (e.g., listening comprehension) not adequately represented	Administration and interpretation of results requires a specifically trained examiner; rather limited coverage of broad cognitive abilities of CHC model

Note. CHC = Cattell–Horn–Carroll; Gc = crystallized intelligence; Gf = fluid intelligence.

Flanagan, 1999). Notwithstanding, the WJ–III is a comprehensive measure that has impressive psychometric properties, may be applied across a broad age range, and appears relatively easy to administer and score (e.g., Braden & Alfonso, 2003; Edwards & Oakland, 2006; Gregg, Coleman, & Knight, 2003; Gridley, Norman, Rizza, & Decker, 2003). Most important, perhaps, its mapping to contemporary models of intelligence, particularly the CHC model, is highly compelling.

WISC–IV Integrated

The main criticisms of the WISC–IV Integrated have to do with the failure of the scale to uncover the proposed conceptual structure, as well as the seemingly thin research supporting one of the components of the test, the process component. The manual also contains limited information supporting the validity of interpretation of scores, especially those that emerge from comparisons. As Kamphaus (1998) noted of earlier versions, many interpretations of WISC data rely heavily on clinical interpretations and not empirical findings; there is nothing in the WISC–IV's makeup to suggest this problem has been averted. Although this measure is perhaps the most popular and widely used of all of the cognitive tests reviewed in this section, it also appears to be one of the most problematic from the standpoint of contemporary intelligence theory.

SB–V

The SB–V is an empirically sound instrument. Even so, far too many broad abilities of plausibly important significance are simply not represented (e.g., listening comprehension). The point is nontrivial because listening comprehension is thought to be an important component of reading competencies (see McGrew & Flanagan, 1999), and not representing it in a battery designed for school-age children is a potentially serious omission. However, the relative ease of administration and scoring and the versatility of the SB–V allows its users to diagnose a wide variety of developmental disabilities and exceptionalities in such domains as clinical and neuropsychological assessment, early childhood assessment, and psychoeducational evaluations for special education placements.

KABC–II

The KABC–II appears flexible, theoretically and psychometrically sound, and versatile. The measure has a twofold theoretical base (CHC and Luria's [1966] neuropsychological model[1]), making this instrument appropriate in a broad range of domains, ranging from clinical to educational. Compared with the three intelligence test batteries discussed earlier, this measure appears to more fairly assess children of different backgrounds and with diverse problems, with small score differences between ethnic groups. It is appropriate for use with children whose language skills are significantly limited because Luria's (1966) model-based assessments completely exclude verbal ability. A significant research base supports this measure, with a number of studies demonstrating acceptable psychometric properties with samples drawn from a number of countries across the world. The new edition represents an improvement over the previous version, so the test is likely to gain further popularity in both clinical and educational practice.

Dangers Associated With Intelligence Testing and Interpretation

Decisions to use intelligence tests to make consequential decisions should be made with a clear understanding of the potential dangers and the possible negative side effects associated with both their use and their misuse. Critics of intelligence tests have suggested that they minimize the significance of creativity, character, and practical skills; unfairly stratify test takers by race, gender, class, and culture;

[1]Luria (1966) believed that three functional blocks constituted the brain's basic operations. These three blocks, or functional systems, are responsible for (a) arousal and attention (Block 1); (b) the use of one's senses to analyze, code, and store information (Block 2); and (c) the application of executive functions for formulating plans and programming behavior (Block 3). Empirical research has supported Luria's structure and the existence of the three functional units (see, e.g., Naglieri & Das, 1997). Luria also stressed the integration and interdependence of these blocks and claimed that the joint operation of several brain systems is crucial for children to acquire new material efficiently. The KABC–II focuses on the integrative nature of the three functional systems and includes measures of simultaneous processing that not only require the analysis, coding, and storage of incoming stimuli but also demand executive functioning and problem solving for success.

and reinforce the notion that people are born with a certain amount of intellectual potential that determines their success in life. If used appropriately, however, the results of such assessments have proven tremendously instrumental in a plethora of contexts ranging from psychoeducational evaluations for special education, gifted student placements, and early childhood assessments to adult social security and workers' compensation evaluations and forensic evaluations.

FUTURE DIRECTIONS IN INTELLIGENCE RESEARCH

In the sections that follow, we highlight some selective issues for extending both the concept and the assessment of intelligence. We begin by discussing the importance of more fine-tuned assessment of the cognitive processes likely evident whenever taking a test. Next, we briefly discuss emerging research examining still further potential abilities, specifically social and emotional intelligence and creativity. We conclude with an appeal to establish a greater rapprochement between structural models such as Gf–Gc theory and public policy.

Greater Emphasis on Cognitive Processes Assessment

Many of the intelligence tests reviewed are administered in a paper-and-pencil format or otherwise involve manipulation of three-dimensional stimulus materials or involve oral responses to standardized questions, often without a systematic means of objectively recording the respondents' patterns of behavior. The precise measurement of many cognitive processes, enacted within fractions of a second, is not possible. For this reason, the range of commercially available standardized intelligence tests attempting to assess disparate cognitive processing constructs appears to have been restricted. In the future, it is likely that intelligence testing will move toward assessment of cognitive processing constructs both for improved construct validity and for more potentially meaningful diagnosis and remediation of cognitive impairments. Measuring an increased range of cognitive processes is possible through the implementation of computer technologies; more automated, real-time data capture and analyses; item-generative procedures; and advances in statistical techniques such as item–response theory, structural equation modeling, and Bayesian and dynamic systems approaches.

There is a school of thought that to realize these goals, the future of cognitive assessment rests with computer games and related technology. An attraction of this type of approach is that one can construct an environment that youths, adolescents, and even adults find engaging, and at the same time, the technology is such that numerous elements of performance can be captured. Notably, there have recently been some attempts to measure broad cognitive abilities of Gf–Gc theory in a gaming environment. For example, McPherson and Burns (2007) were able to devise a measure of processing speed that had impressive psychometric properties, calling for researchers to develop gamelike tests for other forms of intelligence.

Emergence of "New" Intelligence Constructs

Considerable impetus for the investigation of new constructs, which might profitably extend intelligence testing at both practical and theoretical levels, comes from applied psychology. Here, the (combined) validity coefficients of measures of intelligence, personality, and other individual differences variables, for the prediction of educational, workplace, and other forms of success, appears no higher than 60 (see, e.g., Matthews et al., 2003; Schmidt & Hunter, 1998). On the theoretical side, beyond constructs assessed by intelligence tests, there also appear factors, both cognitive and noncognitive, that might be said to support intelligent behavior. For example, the concept of emotional intelligence extends the idea of human cognitive abilities by suggesting that social and emotional factors can affect intelligent behavior (Mayer, Roberts, & Barsade, 2008; Roberts, Zeidner, & Matthews, 2001; Zeidner, Matthews, & Roberts, 2009). Further still, Sternberg (1996) has suggested that creativity and practical intelligence are supplemental to analytic intelligence in producing intelligent behavior and has suggested methods for both measuring and enhancing these factors. It may be recalled that these various research foci were important components of Guilford's (1967, 1988) model, and although his general model may be in error, it should not be underestimated for its visionary quality. Research that attempts to relate constructs such as social and emotional intelligence to measures from Gf–Gc theory is currently lacking, although we have recently been engaged in studies that redress this imbalance (see Roberts, MacCann, Matthews, & Zeidner, 2010).

Need for a Rapprochement Between Hierarchical Models of Intelligence and Public Policy

It is perhaps trite to acknowledge that intelligence and intelligence testing are consequential in informing public policy. Consider, for example, the large number of health policies that have been put into place across developed nations, largely because of established research showing that both nutrients and toxins influence cognitive function (see, e.g., Olness, 2003). How policies play out in other domains is less straightforward: Ethnic gaps in achievement and the role of intelligence in these gaps, in particular, has led to considerable public debate (see, e.g., Herrnstein & Murray, 1994; Neisser et al., 1996), with little clear headway being made in addressing these gaps. It is perhaps noteworthy that the implications of these findings have not been properly viewed through the lens of contemporary knowledge of Gf–Gc theory. When this is done for the data supporting the bell curve, for example, almost all of the conclusions reached appear relevant solely to crystallized intelligence (Roberts et al., 2000). In the future, it would appear incumbent on policymakers, armed with the knowledge of important differences between broad factors of cognitive ability, to begin shaping policy that takes into account each independent dimension rather than assumes the existence of a singular, general intelligence.

CONCLUSION

Our exposition suggests that much work still needs to be done in intelligence research and that the data paint a far from incontrovertible picture surrounding the present knowledge of the range of human cognitive abilities and the best means of assessing them. Although intelligence traditionally has been examined through the lens of psychology, future inquiries are destined to come from the cross-pollination of ideas in neuroscience, genetics, economics, psycholinguistics, and anthropology, to name a few. A clear and important policy implication of such research is that proper definition and adequate assessment of intelligence eventually will lead to improvement in the ability to gauge an individual's current level of intellectual functioning and to develop and prescribe instructional interventions that will maximize each individual's potential.

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