Common and Variable Aspects of Intelligence

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Intelligence has been conceptualized as a product of the overall physiological efficiency of the brain itself and crucial for adaptive problem solving. David Wechsler (1944) defined intelligence as "the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment" (p. 3). This chapter considers the assessment of human intelligence from a broad perspective of brain-behavior relationships as an aid to understanding implications of normal as well as abnormal intellectual ability through the discussion of biobehavioral paradigms related to human intelligence. All psychologists have a strong interest in intelligence from theoretical, social, and clinical perspectives. Level of intelligence is important to establish in multiple contexts as a selection and placement criterion as well as an aid in diagnosis and treatment, including as a baseline of overall mental function against which more specific cognitive skills may be compared. Human intelligence as a clinical biobehavioral concept was initially proposed by Alfred Binet. Essentially, City of Paris, France, public school officials were concerned that children of impaired cognitive ability were not being discriminated from children of normal cognitive ability and that was disruptive to the education of all children because of the need for differential education methods for both groups of children. The education officials requested Binet to develop a method to discriminate children of impaired cognitive ability from children of normal cognitive ability to determine which children should be in special education, and he subsequently created the first successful standardized intelligence test (Binet and Simon 1905, 1908). It is noteworthy that the task was one of practical significance – selection and appropriate placement of children in an academic context, similar to what is done today through the SAT Reasoning Test (previously the Scholastic Aptitude Test and Scholastic Assessment Test) or Graduate Record Exams (GRE).

Later, David Wechsler developed an intelligence test for adults to aid in clinical assessment (Wechsler 1939). Wechsler's older brother (Israel Wechsler) was a neurologist (Chief of Neurology at Bellevue Hospital in New York City), and the

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need for an intelligence test for standardized examination for neurological patients may have been an influence. Wechsler had been a research assistant to Robert Yerkes when Yerkes was in charge of assessing the 17 million men who were drafted to fight in World War I. The 17 million men were assessed with psychological tests commonly used at that time to select which men should be selected for officer training (Wechsler 1939). Two tests were developed, the Army Alpha and the Army Beta. Army Alpha was a verbal test of mental abilities used to assess recruits that were native English speakers. After using Army Alpha, it was noted that many recruits were immigrants from Eastern Europe and Italy who were not native English speakers but might be able to be good officers. To assess these nonnative English speakers properly, Army Beta, a nonverbal mental abilities test, was developed. The psychological tests that had been most successful for selecting officers during World War I were used by Wechsler when he developed his own first intelligence test (Wechsler 1939).

Wechsler combined tasks similar to those on the Army Alpha and Beta tests (verbal and nonverbal tests) to form the Wechsler-Bellevue Intelligence Scale (Wechsler 1939). The most important contribution of Wechsler (1939) was methodological as he standardized the administration and scoring of the tests and normed the intelligence test in large national samples of adults (Wechsler 1952) and introduced age-corrected deviation scaled scores for interpretation of intelligence test performance. Clinical psychology as a field has thus had a long-term interest in evaluating intelligence (Horton and Wedding 1984).

The Role of "*g*" In Neuropsychological Models of Intelligence

The Greek philosopher Aristotle first suggested that intellect could be assessed by a single mental ability variable, *nous* (Detterman 1982). As Aristotle was also the tutor of Alexander the Great, Aristotle clearly had some academic experience with an individual of great intelligence – his own student who became the ruler of most of the then known world. The concept of *g* has been conceptualized as the average of an individual's higher-level cognitive abilities as assessed by many different types of cognitive tasks. Put another way, *g* can be conceptualized as a latent trait rather than an observable outcome.

Research on *g* has been extremely important in psychology, and *g* has been a very useful means of conceptualizing overall intellectual ability (Aluja-Fabregat et al. 2000; Kane 2000). Jensen (1998) after reviewing the empirical research for the presence of a general cognitive ability factor in intelligence concluded that if a very large number of tests were used to assess a very wide spectrum of mental abilities, then a *g* factor would always be found (Jensen 1998). Failures to find a *g* factor in prior research studies were attributed to failures to use a large enough number of tests and assess a large enough different types of abilities (Jensen 1998).

Moreover, researchers (Reynolds and French 2003) have suggested the study of *g* and the study of cognitive processing styles are complementary areas in intelligence research investigation. Indeed, evidence for simultaneous and successive information processes in the human brain may be complementary to the concept of a *g* factor. The verbal and performance factors found in research studies of intelligence testing are examples of the related cognitive factors in diverse populations (Reynolds 1981). The abstract concept of *g* can be seen as possibly complementary to differences in the level or efficiency of information processing (Das et al. 1979; Detterman 1982). For example, Travers (1977) and Luborsky et al. (1971), in studies of psychotherapy outcome research, found that the best predictor of successful psychotherapy outcome was the intelligence level (i.e., *g*) of the individual receiving psychotherapy. The researchers unfortunately seem to have overlooked the option of assessing the contribution of variable of the intelligence level of the person delivering the psychotherapy to psychotherapy outcome but admittedly that would be a difficult study to conduct for multiple reasons. In addition, rehabilitative success of brain-injured neurological patients is best predicted by the pre-morbid intelligence level of the individual patients (Golden 1978).

It is noteworthy that the abstract concept of *g* has been considered limited by the biological integrity and physiological efficiency of the human brain (Brand 1996; Vernon 1998). Harmony (1997) and Languis and Miller (1992) have suggested that physiological measures, such as the EEG and/or auditory evoked potentials, could be utilized to assess aspects of cognitive ability. Jensen's research (1978, 1998) on reaction times and evoked potentials had suggested that *g* could be conceptualized as general physiological efficiency of the central nervous system. Future understanding of the concept of *g* will require elucidation of the method and components of information processing in the brain. It is possible that further elucidation of brain-behavior models may contribute to understanding of *g*. Consideration of the relationship of *g* to contemporary models of brain-behavior may prove very helpful.

Luria's Brain-Behavior Model

Alexander R. Luria, a Soviet neurologist and neuropsychologist, had important insights into brain functioning (Horton 1987). Perhaps the most important insight was the concept of the complex functional system (i.e., multiple diverse brain areas subserve particular behavioral abilities) (Horton 1987). Using the cultural-historical theory of brain-behavior relationship, Luria was able to perform an evaluation of an individual's neurological status (Horton 1987). Grossly oversimplified, it could be averred that he (Luria 1973) described sensory and motor functions of the brain as having highly specific functional localizations, while higher-level mental processes required coordination of multiple areas of the brain. In other words, lower-level functions were hardwired in specific neuroanatomical areas but higher-level functions were widely distributed throughout the human brain. Put still another way, higher-level human brain functions require multiple areas of the brain to accomplish complex behaviors, but lower-level human brain functions (i.e., sensorimotor functions) are localized in a specific area of the brain (Reynolds 1981). Higher-level human brain functions are process specific, and processing of information requires coordination of diverse neuroanatomical brain sections (Ashman and Das 1980). Higher-level human brain organization (Luria 1973) further was characterized as the brain's higher-level processing being organized into three major human brain areas. The first human brain area included the brainstem and reticular formation, the midbrain, pons, and medulla. The second human brain area included the parietal, occipital, and temporal lobes (Luria 1973). The third human brain area included all of the cerebral cortex anterior to the sensory-motor strip (i.e., Rolandic fissure). The three major higher-level brain areas (Luria 1973) all function in a dynamic reciprocal interaction to subserve higher-level cognitive processing, or in other words the higher-level processing depends on multiple diverse areas of the human brain (Reynolds 1981). As earlier noted, lower-level functions are more hardwired to specific neuroanatomical brain areas.

The notion of the brain as a dynamic functional system, it should be acknowledged, was first proposed by Hughlings Jackson, an English physician who lived in the nineteenth century, and was further elucidated by Luria (Horton 1987). Essentially, higher mental processes are seen as based on multiple diverse human brain areas communicating and working together, and as a result higher-level functions may be disrupted by the destruction of a communication channel of the functional system (Luria 1964). Further, disturbances of higher-level mental functions can be influenced based on the specific localization of the brain damage (Luria 1964). Therefore, rehabilitation of the human brain higher-level functional system, if there is specific brain damage, will require the brain to assemble an alternative sequence of human brain areas working together to perform specific behavioral tasks in a new way (Luria (1964). The localizing brain area responsible for behavioral disturbance can be determined by qualitatively analyzing the difficulty experienced in performing a specific behavioral task (Luria 1964).

Neuroanatomical Area One

The first neuroanatomical area of the human brain, the brain stem, subserves maintaining consistent arousal, attention, and concentration abilities. The energy level and tone of the entire human cerebral cortex allow a stable platform to organize the various higher-level cognitive functions of the human brain. The brain stem, first neuroanatomical area, includes the reticular formation, the posterior hypothalamic and brainstem portions of the brain. Damage to the first neuroanatomical area of the human brain can cause lowering of the level of consciousness in the human cerebral cortex, disrupting higher-level cognitive functioning thereby giving rise to disorganized behavior.

Neuroanatomical Area Two

The area posterior to the central sulcus (i.e., parietal, occipital, and temporal lobes) is included in the second neuroanatomical area of the brain. The second neuroanatomical area of the human brain is primarily receptive in nature, integrating diverse sensory inputs, storing, integrating, and organizing sensory information. The second neuroanatomical area of the brain allows perception, analysis, and synthesis of sensory stimuli (e.g., auditory in the temporal lobes, visual in the occipital lobes, and tactile in the parietal lobes). Within the second neuroanatomical area of the brain, each lobe sensory stimuli processing (auditory in the temporal lobes, visual in the occipital lobes, and tactile in the parietal lobes) is organized into three hierarchical zones. The *primary zone* perceives and retains incoming sensory stimuli. The *secondary zone* analyzes and organizes sensory information from the *primary zone*. The *tertiary zone* receives sensory information (auditory in the temporal lobes, visual in the occipital lobes, and tactile in the parietal lobes) from the multiple *secondary zones of the three lobes* and organizes the information into higher-level cognitive processes subserving complex human behavior.

Neuroanatomical Area Three

The frontal lobes which involves the initiation, development, and monitoring of plans for behavior are included in the third neuroanatomical area of the human brain. In other words, frontal lobes, the third neuroanatomical area, receive and evaluate organized sensory input from the first and second neuroanatomical areas of the human brain and perform executive functions integrating the information to subserve complex adaptive problem solving in a managerial role (Luria 1973; Obrzut and Obrzut 1982). The frontal lobes, in addition to direct connections to the second neuroanatomical areas, are also directly connected to the reticular formation in the first neuroanatomical area of the brain. This series of reciprocal communication neural networks mediates the activation and processing of higher-level cognitive processing throughout the human cerebral cortex. Performing an executive function, the frontal lobes direct attention and concentration processes in the human brain. The direct connections among the first, second, and third neuroanatomical areas of the human brain facilitate reciprocal neural network communication systems that facilitate complex human decision making and adaptive problem solving based on arousal, attention, and organized sensory input. The coordination of first neuroanatomical area of the brain with the second and third neuroanatomical areas thereby facilitates the initiation, development, and monitoring of behavioral plans and their timely, efficient, and effective evaluation. In contrast with arousal role of the first neuroanatomical area and the receptive role of the second neuroanatomical area, the third neuroanatomical area of the brain has an expressive, generative role. In a nutshell, it is noted that human higher-level cognitive functioning is facilitated by the dynamic and reciprocal interplay of the three neuroanatomical area of the brain (Luria 1964; Golden et al. 1979; Golden 1987; Horton 1987).

Simultaneous and Successive Cognitive Processes

Further elucidation of the functioning of the second neuroanatomical area (Luria 1964) involves appreciation of modes of information processing. These can be characterized usefully as simultaneous and successive (or sequential) cognitive processes. Put another way, sensory information can be processed in sequence or one element at a time in order or simultaneously where all of the information is processed as a whole or as a gestalt, in other words, describing a group of trees as oak, pine, birch, etc., or as a forest. Simply put, sensory stimuli, in the second neuroanatomical area, can be processed through either simultaneous or successive means (Kaufman 1979b). Simultaneous and successive processes can be used to process any specific sensory modality (i.e., auditory, visual, tactual, etc.) or stimulus elements (verbal, nonverbal) (Ashman and Das 1980). Which type of processing, either simultaneous or successive cognitive processing, is most efficiently effective will depend on the task demands, attention demands required by the task, and preferred means for completing the task (Hall et al. 1988; Watters and English 1995; Willis 1985). Verbal communications may be processed effectively through linear successive methods such as dictating or writing a letter. Spatial tasks, such as map reading, may be processed effectively through simultaneous-processing strategies. Or to use another example, a forest ranger might know each type of tree in a forest, but a hiker would be more concerned with the concept of forest.

Simultaneous Processing

This is the synthesis of separate elements into spatially related groups with direct access to any separate element (Das et al. 1979). Within the second neuroanatomical area, the right occipital and parietal lobes of the human brain subserve simultaneous information processing (Naglieri et al. 1983; Willis 1985). Commonly considered measures of simultaneous processing can include visual-spatial ability tests (Kirby and Das 1977).

Successive Processing

In contrast, successive (or sequential) processing is linear accessing of information in a serial fashion (Das et al. 1979). In the second neuroanatomical area, the left temporal lobe of the brain subserves successive (or sequential) processing (Naglieri et al. 1983; Willis 1985). The successive (or sequential) processing requires the maintenance of the temporal order of input of information (Naglieri et al. 1983). An example of successive (or sequential) processing might include learning to read using a phonetic approach (Gunnison et al. 1982). That is not to say that reading cannot be accomplished by simultaneous processing such as the whole word approach, but rather with a phonetic approach, successive (or sequential) processing is more efficient.

Hemispheric Specialization and Simultaneous and Successive Cognitive Processes

Different cerebral hemispheres are thought to be more efficient with either simultaneous or successive processing (Naglieri et al. 1983). The left cerebral hemisphere may be more efficient in performing linguistic, serial, and analytic tasks. The right hemisphere may be more efficient in performing visual-spatial and gestalt-holistic tasks (Bever 1975; Bogen 1969; Dean and Reynolds 1997; Gazzaniga 1970; Harnad et al. 1977; Kinsbourne 1978, 1997; Naglieri et al. 1983; Schwartz et al. 1975; Segalowitz and Gruber 1977; Willis 1985). Modes of information processing appear likely related to hypothesized differences in cerebral hemispheric processing, and as earlier mentioned, the advantage is that one cerebral hemisphere may be more efficient in processing particular stimuli, but that does not mean that the other cerebral hemisphere cannot also process that same stimuli but rather a relative degree of efficiency may be lost. For example, there are persons who read using a whole word rather than a phonetic approach. Indeed, not all languages are phonetically based, so whole word approaches are essential in some languages. Utilization of specific cognitive processing modes may optimize the efficiency of these hemispheric brain functions.

Cerebral hemispheric asymmetries of functioning, as previously pointed out, are relative preferences for *process-specific* strategies rather than *stimulus-specific strategies*. The mode of higher-level cognitive processing for task performance depends on multiple factors which include, but are not limited to, specific task demands, level of attention required for the task, individual cognitive abilities, genetics, and cultural traditions (Cumming and Rodda 1985; Hall et al. 1988; McCallum and Merritt 1983; Watters and English 1995; Willis 1985). The need for specific types of manipulation of stimuli can also be a reason for selection of a specific hemispheric (e.g., Dean 1984; Grimshaw 1998; Mateer et al. 1984; Obrzut et al. 1985; Ornstein et al. 1980; Piccirilli et al. 1991; Tous et al. 1995).

Hemisphericity and Cognitive Processing

Reynolds (1981) conceptualized hemisphericity as preference for cognitive information-processing style independent of cerebral dominance. Hemisphericity can be defined as the tendency of an individual to rely differentially on the higher-level information-processing style of one cerebral hemisphere (Reynolds 1981). Previous research appears to be essentially consistent with hemispheric specialization (Dean and Reynolds 1997). Optimal higher-level cognitive functioning may require utilization of both modes of information and also being able to shift the cognitive information-processing mode in response to multiple factors (Gazzaniga 1974, 1975). At the same time, dysfunctional hemisphericity may impede optimal higher-level cognitive functioning (Newell and Rugel 1981; Roubinek et al. 1987). Research, over many years, has demonstrated that identifying the preferred mode of cognitive information processing (hemisphericity) may be advantageous in terms of addressing and remediating academic learning problems (Faust et al. 1993; Gunnison et al. 1982; Paquette et al. 1996; Roubinek et al. 1987; Sonnier 1992; Sonnier and Goldsmith 1985). Research on intelligence reviewed thus far has focused on intelligence as a single factor *g*, a brain-based behavior model, and different modes of cognitive information processing.

Halstead's Theory of Biological Intelligence

Simply put, theoretical interest in the human mental abilities subserved by the human frontal lobes was the focus of Ward Halstead's research program (Halstead 1947). This research interest also included the concept of intelligence (Halstead 1947). It might be noted that Boring (1930) has considered the concept of intelligence as what intelligence tests measured which is, of course, tautological.

Halstead accepted Boring's definition of intelligence as psychometric intelligence which was postulated to be what was measured by the intelligence tests (Halstead (1947). In contrast, however, Halstead also conceptualized a type of intelligence that was different from psychometric intelligence (Halstead 1947).

Biological intelligence as conceptualized by Halstead (1947) was human adaptive abilities as subserved by an intact uninjured brain, in other words, human adaptive abilities that were significantly impaired following brain damage.

The concept of biological intelligence was hypothesized in response to perceived limitations of intelligence tests. Halstead (1947) observed that in many cases, patients who had brain injuries were still able to score well on intelligence tests despite clear brain damage and significant adaptive behavior problems in daily living. Halstead (1947) conceptualized that there was an additional brain-based latent construct that was sensitive to human adaptive abilities but poorly evaluated by intelligence tests. In other words, Halstead agreed with David Wechsler's definition (1944) of intelligence as "the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment" (p. 3) but found then contemporary intelligence tests inadequate to satisfy David Wechsler's definition (1944) of intelligence and sought to find a brain-based latent construct that would better satisfy Wechsler's definition (1944).

In order to research the latent construct of biological intelligence, Halstead (1947) established an experimental brain-behavior research program at the University of Chicago Medical School focused on studying the biological integrity of the human brain (Horton and Wedding 1984). Halstead (1947) developed a number of sensitive measures to the behavioral deficits of brain-injured persons which Halstead postulated represented the abstract concept of biological intelligence and were distinct from psychometric intelligence. Of particular interest is Halstead's factor analytic attempt to identify the aspects of higher cognitive functions that were involved in biological intelligence (Halstead 1947).

Halstead (1947) extracted four basic factors of biological intelligence, and these factors are described below:

C, *the integrative field factor*. The ability to adapt to new situations and to integrate new information was postulated as the integrative field factor (Reitan 1994). Tests that had loadings on factor C included the Halstead Category Test, the Henmon-Nelson Tests of Mental Ability, the Speech-Sounds Perception Test, the Halstead Finger Oscillation Test, and the Halstead Time-Sense Test (Halstead 1947).

A, *the abstraction factor*. The ability to draw meaning from a series of events or to hold in mind abstract nonverbal ideas without the use of past experience. Tests that had loadings on factor A included the Carlo Hollow-Square Performance Test for Intelligence, the Halstead Category Test, the Halstead Tactual Performance Test (memory component), and the Halstead Tactual Performance Test (localization component) (Halstead 1947).

P, *the power factor*. The reserve power available to an amplifier not already functioning at peak ability was postulated to be the power factor. Tests that had loadings on factor P included the Halstead Flicker-Fusion Test, the Halstead Tactual Performance Test (recall component), the Halstead Dynamic Visual Field Test (central form), and the Halstead Dynamic Visual Field Test (central color) (Halstead 1947).

D, *the directional factor*. An attentional component. Tests that had loadings on factor D included the Halstead Tactual Performance Test (speed component) and the Halstead Dynamic Visual Field Test (peripheral component) (Halstead 1947). The first three factors, C, A, and P, were interpreted as process factors of biological intelligence, and D was interpreted as the factor through which expressions of factors C, A, and P were directed.

It is noteworthy that both factors C and A had had significant loadings from intelligence tests but the intelligence tests loaded on different factors. The tests measuring the four factors significantly differentiated between individuals with documented head injury and individuals with no documented history of head injury (Halstead 1947).

Moreover, an average of the measures (the Halstead Impairment Index) was the best measure in differentiating these individuals (Halstead 1947). Unfortunately, as the concept of biological intelligence was postulated to be related to the integrity of the frontal lobes, subsequent experimental research studies couldn't cross-validate a relationship between the frontal lobes and HII (Reitan 1975), thus failing to confirm the concept of biological intelligence. In addition, as previously noted, tests of intelligence did load on factors extracted from Halstead's tests so the latent construct biological intelligence appeared to overlap rather than be orthogonal to psychometric intelligence. Interestingly, Halstead's tests were better able to differentiate brain damaged from normal subjects than intelligence tests alone but exactly why remains elusive.

Reitan (1994) had validated a modified and augmented neuropsychological test battery based on Halstead's tests as a core to improve diagnostic accuracy (Hevern 1980; Reed 1985; Swiercinsky 1979). It is noteworthy that formal intelligence testing has always included as an integral portion of Reitan's comprehensive clinical neuropsychological test battery, in addition to Halstead's core tests and a number of additional test procedures added to assess brain areas not related to intelligence tests. It is noteworthy that Halstead's factor structure (Horton and Wedding 1984) was very similar to the factor structure found for the age-appropriate Wechsler scales (Kamphaus 2001; Kaufman 1994). Basically, the contemporary Wechsler scales have a factor structure which consists of verbal comprehension, perceptual organization, working memory, and processing speed factors. In other words, very similar to the four factors identified by Halstead (1947).

Subsequent factor analysis studies with neuropsychological tests have produced comparable results. A few examples are cited. A study with adult neuropsychiatric patients (Fowler et al. 1988) extracted five factors (verbal comprehension, perceptual organization, sensory attention, primary motor, and tactual-spatial abilities). Also, a study of children aged 9–14 (Brooks et al. 1989) extracted 4 factors (simple motor, tactile kinesthesis, memory/attention, and nonverbal visual-spatial memory). In addition, a study with children aged 9–12 (Francis et al. 1992) extracted 5 factors (simple motor skill, complex visual-spatial relations, simple spatial motor operations, motor steadiness, and speeded motor sequencing). Moreover, a study with younger children aged 5–7 (Foxcroft 1989) extracted six factors (analytic-synthetic visual motor ability, perceptual organization, cross-modality motoric efficiency, directed motor speed, patterned critical discrimination, and strength). Briefly put, multiple factor analysis studies appear to extract factors which are relatively similar to factors found from the age-appropriate Wechsler scales (Kamphaus 2001; Kaufman 1994).

Therefore, conceptualizations of intelligence that are consistent with David Wechsler's (1944) definition of intelligence as "the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment" might be seen as loading on the above factors. The relationship with *g* and the above factors needs to be reconciled. A possible answer, however, will be addressed in the next sections.

Contemporary Wechsler Scales of Intelligence

There are three contemporary Wechsler intelligence scales designed to assess adults, school-aged children, and children in preschool and primary grades. They include the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV) (Wechsler 2008), the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV) (Wechsler 2003), and the Wechsler Preschool and Primary Scale of Intelligence – Third Edition (WPPSI-III) (Wechsler 2002) and all allow examiners to compute full-scale IQs. The WAIS-IV is designed to assess from ages 16 to 90 and 11 months, the WISC-IV is designed to assess from ages 6 to 16 and 11 months, and the WPPSI-III is designed to assess from age 2 years and 6 months to age 7 years and 3 months. In terms of factor structures as recommended for clinical interpretation in the technical and interpretation manuals, there is a great deal of similarity. For the WAIS-IV (Wechsler 2008), the recommended factor structure forms the bases for the Verbal Comprehension Index, the Perceptual Reasoning Index, the Working Memory Index, and the Processing Speed Index. Similarly for the WISC-IV (Wechsler 2003), the recommended factor structure includes again the Verbal Comprehension Index, the Perceptual Reasoning Index, the Working Memory Index, and the Processing Speed Index. Essentially both the WAIS-IV and WISC-IV are reported to have the same factor structure. For the WPPSI-III (Wechsler 2002), however, there are differences depending on the age of the child. Essentially from ages 2 years and 6 months to 3 years and 11 months, a two-factor model is recommended with a verbal intelligence quotient (VIQ) and performance intelligence quotient (PIQ). From age 4 to 7 years and 3 months, a three-factor model is recommended with a verbal intelligence quotient (VIQ) and performance intelligence quotient (PIC) and a processing speed quotient (PSQ). In summary, all of the Wechsler scales of intelligence show verbal and performance factors at every age level. For the WPPSI-III, a two-factor model of verbal and performance is preferred from ages 2 years and 6 months to 3 years and 11 months; in a three-factor model of verbal performance and processing, speed is preferred from ages 4 to 7 years and 3 months. For the WISC-IV and WAIS-IV, four-factor models (verbal comprehension, perceptual reasoning, working memory, and processing speed) are preferred. As earlier mentioned, all of the Wechsler scales allow the computation of a full-scale IQ. Recent research studies (Canivez and Watkins 2010) supported the WAIS-IV as a measure of general intelligence but noted the remaining factor structure accounted for small portions of total and common variance. Benson et al. (2010) suggested that a Cattell-Horn-Carroll (CHC) structure provides a better description of test performance with abilities that include crystallized ability (Gc), fluid reasoning (Gf), visual processing (Gv), short-term memory (Gsm), and processing speed (Gs). Moreover, Weiss et al. (2013a) found that either a four- or five-factor structure fits the data, but a five-factor structure was a better fit with a quantitative reasoning (RQ) factor included.

For the WISC-IV, Keith et al. (2006) suggested the scoring structure was not supported and the Cattell-Horn-Carroll (CHC) theory was a better fit, but Watkins (2010) found the four first-order factors as suggested by the WISC-IV test manual (Wechsler 2003). More recently, Weiss et al. (2013) found that either a four- or five-factor structure fits the data and both were suitable, and the five-factor model included inductive reasoning (IR).

A common concern was that the *g* factor was the majority of the variance and other factors were quite small.

Carroll's Theory of Intelligence

Carroll's (1993) three-stratum theory of intelligence has averred that the latent traits tapped by intelligence tests are independent of the specific test battery. Carroll (1993) has postulated that numerous mental ability tests measured the same abilities which Carroll labeled crystallized, visual-perceptual, and memory abilities. In interpreting extant research findings, Carroll (1993) has proposed there are three strata of intelligence. An important feature is the reconciliation of previous research results related to the assessment of human intelligence by combining the Cattell-Horn notion of crystallized G (Gc) and fluid G (gf) with the Carroll paradigm into the Cattell-Horn-Carroll (CHC) theory (McGrew 2009). In Carroll's (1993) theory, the third stratum is unitary or, put another way, is composed of one construct only, *g* as previously described. Multiple studies of human intelligence have found that *g* accounts for the major portion of variance assessed by intelligence test batteries. Similarly, intelligence tests are strong and consistent predictors of very important social outcomes, such as academic achievement (Binet and children in the Paris Public Schools) and occupational performance (Wechsler and officer candidates in the US Army in World War I and in addition the SATs, GREs, etc.). The predictive ability is directly related to the amount of *g* measured by the intelligence test. Simply put, intelligence tests with greater amounts of *g* are significantly better predictors of important outcomes in society than are intelligence tests with lower amounts of *g*. Clearly intelligence tests with large amounts of *g* have important purposes in society, especially in terms of prediction of success in academic and occupational settings. It is a conundrum that while the psychometric concept of *g* has proven useful in society for over a century, the full understanding of the latent concept of *g* remains elusive and is not yet completely understood by psychologists even after a century of research and clinical application. The CHC theory posits various types of *g* such as Gc and Gf among others.

Carroll's (1993) second stratum of traits is composed of combinations of stratum one measures and second-stratum measures that combine to form the third stratum. Typically, stratum one measures are more specific traits of interest. Stratum one measures are combined to become stratum two measures and result in enhanced measurement of complex higher-level cognitive traits such as verbal and nonverbal intelligence. Similarly, stratum two measures are then in a hierarchical fashion combined to allow for the measurement of a complex stratum three trait, such as the latent construct of intelligence or *g*. Concepts such as fluid intelligence, crystallized intelligence, general memory and learning, broad visual perception, broad auditory perception, and processing speed are examples of second-stratum traits (Carroll 1993). Multiple research studies appear to suggest second-stratum traits can be ranked in terms of their abilities to assess *g* (Kamphaus 2001). Second-stratum traits which involve reasoning abilities are better measures of *g*. Examples of second-stratum traits that involve abstraction abilities might be seen as general sequential reasoning, induction, deduction, syllogisms, series tasks, matrix reasoning, analogies and quantitative reasoning, etc. (Carroll 1993). An example of a contemporary intelligence test that uses the CHC theory as a basis is the Reynolds Intellectual Assessment Scale (RIAS) which will be described in the next section.

Reynolds Intellectual Assessment Scale (RIAS)

The Reynolds Intellectual Assessment Scale (RIAS) (Reynolds and Kamphaus 2003) follows the more contemporary Carroll (1993) theoretical model of intelligence model. The RIAS has demonstrated impressive evidence for its interpretation as a measure of intelligence (i.e., validity) (Beaujean et al. 2010) as well as being time efficient, user-friendly for administration and scoring, and not having a disparate impact when used to assess members of minority groups, different genders, or groups of clinical patients. The RIAS proposed two-factor structure (verbal intelligence and nonverbal intelligence) has been cross-validated a number of times (Nelson et al. 2007; Dombrowski et al. 2009; Nelson and Ganivez 2012).

Discussion: Common and Variable Aspects of Intelligence

The concept of intelligence appears clearly related to the biological integrity of the brain (Luria 1973). Perhaps not solely to the frontal lobes alone (Reynolds and Horton 2006), but clearly intelligence is related to optimal human brain functioning (Reitan 1994). This chapter has demonstrated that the concept of intelligence can be conceptualized in multiple ways. Carroll's (1993) three-stratum theory of intelligence and the CHC model has found that latent mental traits are test battery independent and numerous tests measured the same latent mental traits tapped by intelligence tests. Multiple research studies have found *g* accounts for the major portion of variance assessed by intelligence test batteries. Also, Carroll's (1993) second stratum consists of higher-level traits such as verbal and nonverbal intelligence (Reynolds and Kamphaus 2003) that are assessed by combinations of stratum one measures. Stratum one measures are typically single subtests that measure a trait of interest and can be combined to form stratum two measures and measure higher-level cognitive abilities such as fluid intelligence, crystallized intelligence, general memory and learning, broad visual perception, broad auditory perception, and processing speed. In turn, stratum two measures are combined into a complex stratum three trait, such as general intelligence as conceptualized as *g*.

Therefore, intelligence can be conceptualized on multiple theoretical levels. Intelligence can be seen as represented by a single score that has impressive predictive abilities, different cognitive processing modes that have implications for higher cognitive functioning and multiple more specific higher-level cognitive ability factors that represent less comprehensive important cognitive skills (Carroll 1993). Relative to the most appropriate conceptualization of the latent trait of intelligence, the two-factor model exemplified by the RIAS appears the right choice. As previously mentioned, it appears the greater amount of *g* accounted for the theoretically more appropriate measure of intelligence. The contemporary intelligence test that maximizes the utilization of *g* is the RIAS. It should be recalled that for the WPPSI-III, the younger age has only two factors and for the older age of the WPPSI-III and for the WISC-IV and WAIS-IV, the later-appearing factors such as working memory and processing speed generally account for lesser amounts of *g*. In the earlier discussion of Halstead's factor analysis of Halstead's neuropsychological tests, it was noted that the first two factors included intelligence tests of the day. Indeed, the WISC-IV and WAIS-IV (Wechsler 2008) now have a measure known as the General Ability Index (GAI) which is a composite score of the three subtests that make up the VCI and the three subtests that make up the PRI. The GAI is proposed to be used when working memory and processing speed measures may have been impaired due to neuropsychological problems (Wechsler 2008).

In other words, the two-factor solution is a superior measure than FSIQ with these clinical groups (Wechsler 2008). Thinking back to the earlier mentioned studies of factor analyses of neuropsychological test batteries, it would seem that human mental abilities in excess of a two-factor solution such as the RIAS and GAI might be better characterized as neuropsychological abilities rather than intelligence (Reynolds and Kamphaus 2003). Simply put, the common structure of intelligence is composed of *g*, and the most *g* loaded two factors (verbal intelligence and nonverbal intelligence) are the best approximation of the latent construct of intelligence and also are the most appropriate basis for a contemporary comprehensive intelligence test.

Development of the various and common aspects of intelligence involve brain mechanisms assisted by cultural-historical experiences, as suggested by Luria (1966, 1973). Intelligence has been conceptualized as certainly influenced by the person's environmental history (i.e., for a discussion of Luria's Cultural-Historical Theory, see Horton 1987, Reynolds 1981) but also with genetic influences mediating the functional development of the various anatomical structures of the brain. Intelligence appears related to an individual's ability to adapt to various life circumstances (Pallier et al. 2000). Further developments of the theoretical foundations of intelligence appear likely to continue to elucidate how the human brain carries out higher-order cognitive functioning. A number of excellent new measures of intelligence have been developed in the past two decades (e.g., Kaufman and Kaufman 1983; Naglieri et al. 2013; Reynolds and Kamphaus 2003), but additional research related to the elaboration of the latent concept of intelligence is needed. The pace of new knowledge is expected to increase and more differentiated and complex understanding of the latent concept of human intelligence is expected.

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