Chapter 8
Neuropsychological Assessment Approaches and Diagnostic Procedures

The purpose of this chapter is twofold. First, we will briefly review three generally accepted approaches to neuropsychological assessment. Second, we will present our transactional assessment approach. This discussion will include evaluation methods for selected functional areas of the central nervous system. The conceptual framework underlying each battery and research with each approach will also be presented.

Approaches to Child Clinical Neuropsychological Assessment

Halstead-Reitan-Indiana Assessment Procedures

The Halstead-Reitan neuropsychological procedures are the most commonly used batteries available in this country (Nussbaum & Bigler, 1997), and the most well researched neuropsychological battery available. Halstead originally developed a series of tests to measure frontal lobe dysfunction in adults, and Reitan later added new tests and recommended the battery for various types of brain damage in children (Reitan & Wolfson, 2004). The Halstead-Reitan batteries contain measures necessary for understanding the brain-behavior relationship in children and adolescents.

Conceptual Model for the Halstead-Reitan Methods

Reitan and Wolfson (1985) indicate that attempts to develop a set of assessment measures resulted in a conceptual model of brain function that is incorporated in the Halstead-Reitan Battery. The battery consists of six categories representing the behavioral correlates of brain function: (1) input measures; (2) tests of concentration, attention, and memory functions; (3) tests of verbal language abilities; (4) tests of visual-spatial, sequential, and manipulatory functions; (5) tests of abstraction, reasoning, concept formation, and logical analysis, and (6) output measures (Reitan & Wolfson, 1985, p. 4).

Reitan and Wolfson (1985) further argue that a neuropsychological battery must have three components: (1) items that measure the full range of psychological functions of the brain; (2) strategies that allow for interpretation of individual brain functions, and (3) valid procedures demonstrated through empirical and clinical evaluation and applications. The neuropsychological batteries for children and adolescents were developed with these components in mind.

Halstead-Reitan Neuropsychological Batteries for Children

Reitan designed two batteries for children, the Halstead-Reitan Neuropsychological Battery for Older Children (HRNB-OC; 9–14 years) and the Reitan-Indiana Test Battery (RINTB; 5–8 years); see Table 8.1. Adolescents 15 years and older are evaluated using the Halstead-Reitan Battery for Adults. Reitan and Wolfson (2004a, 2004b) developed a screening battery for both the HRNB-OC and the RINTB. See Reitan and Wolfson (1992a, 1992b, 2004a, 2004b) for an in-depth description

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Table 8.1 Subtests of the Halstead-Reitan neuropsychological test batteries

Functional Skills	Halstead-Reitan battery (9–14 Years)	Reitan-Indiana battery (5–9 Years)
Motor functions	Finger tapping	Finger tapping
	Grip strength	Grip strength
	Tactual performance test (total time)	Tactual performance (total time)
		Marching test
Visual-spatial[a]	Trails Part A	Matching figures
		Matching V's
		Matching pictures
		Star drawing
		Concentric squares
		Target
Sensory-perceptual	Tactile perception	Tactile perception
	Tactile form recognition	Tactile form Recognition
	Tactile localization	Tactile localization
	Fingertip writing	Fingertip writing
Alertness and concentration[b]	Speech sound perception	Progressive figures
Immediate memory	TPT-memory	TPT-memory
	TPT-localization	TPT-localization
Reasoning	Category test	Category test
	Trails Part B	Color form

[a]Reitan includes Picture Arrangement, Block Design, and Object Assembly from Wechsler scales.
[b]Reitan includes Coding from Wechsler scales.

of the HRNB-OC, the RINTB, and the two screening batteries. Table 8.2 lists the various subtests and the abilities associated with each of these measures.

One of the major shortcomings of the CHRNB has been inadequate norms, and insufficient reliability and validity information (Davis, Johnson, & D'Amato, 2005; Strauss, Sherman, & Spreen, 2006). Over the years Reitan developed and expanded his approach for analyzing the CHRNB (9–14 years) and the RINB (5–8 years). Interpretation typically focuses on a Multiple Inferential Approach, including an investigation of Level of Performance, Pathognomonic Signs, Patterns of Performance, and Right-Left Comparisons. Reitan (1986a, 1987) also developed the Neuropsychological Deficit Scale (NDS), a scoring and interpretation model for these batteries, which incorporates multiple factors. The Functional Organization Approach, proposed by Fletcher and Taylor (1984), is less inferential and places neuropsychological measures within a developmental and contextual framework. Each of these approaches will be briefly described and critiqued.

Multiple Levels of Inference

Reitan (1969) and Selz and Reitan (1979b) developed an interpretive system using four levels of inference: Level of Performance, Pathognomonic-Sign, Differential/Pattern of Scores, and Right-Left Differences.

Level of Performance

Interpretive guidelines for the batteries have discussed the importance of determining the Level of Performance by comparing the child's scores to those of a normative group. In an attempt to expand available norms, Findeis and Wright (1995) developed metanorms from 20 published articles from 1965 to 1990. Tombaugh (2003) also expanded norms for the Trail Making Tests A and B for the 18–89-year-old group, but not for the younger ages.

Standard score comparisons are typically employed in this method, where two standard deviations below the mean are often used as the

Table 8.2 Abilities assessed by the HRNB and HINB in children and adolescents

Function	Subtest	Requirements	R/L Differentiation	Abilities	Localization
Motor	Finger tapping	HINB and NRNB: Children tap mounted key 5–10 second trials with dominant and nondominant hand	Dominant hand expected 10% faster	Motor speed and coordination	Frontal lobe
Motor	Grip strength	HINB and HRNB: Squeeze on dynamometer, alternate hands, 3 trials dominant/non-dominant	Dominant hand expected to be stronger	Sensitive to R/L weaknesses in motor cortex	Frontal lobe
Motor	Tactual performance test (TPT)	HINB & HRNB: (a) Place 6 blocks onto board while blind-folded with dominant/nondominant	Expect 1/3 improvement over trials	Motor and sensory functions, kinesthetic functions	Frontal lobe
Memory		(b) Draw location of blocks from memory	No	Spatial memory	Global
Visual	Trails A[a]	HRNB: Child connects circles sequentially as quickly as possible	No	Motor speed Visual-perception and symbol recognition	
Sensory	Tactile perception test	HRNB and HINB: Back of hand and face are touched either separately or together with eyes closed	Errors on RH-implicates left hemisphere and LH errors implicate right hemisphere	Sensory stimulation	Contralateral parietal lobe
	Auditory perception test	Examiner stands behind child and lightly rubs fingers together. Child indicates where sound is (unilateral or bilateral presentations)	Yes	Auditory stimulation	Temporal lobe
	Visual perception	Examiner produces a finger movement at eye level, above and below eye level	Yes	Visual fields peripheral, unilateral, and bilateral	Visual pathway Visual fields
	Tactile form recognition TRF	Child extends hand through opening in board, and a cross, square, or triangle is placed in hand	Yes	Tactile form recognition (stereognosis)	Parietal lobe
	TRF	Child points to same shape on front of board			
Sensory	Fingertip writing (FTW)	HRNB: Numbers are traced on palm while child watches. Then, 3–are traced on fingertips with eyes closed.	Yes	Tactile perception, attention can be a factor in performance	Peripheral nervous system parietal lobe

Table 8.2 (continued)

Function	Subtest	Requirements	R/L Differentiation	Abilities	Localization
		HINH: X's and O's are traced.			
	Finger localization test	Examiner lightly touches each of child's fingers with eyes closed. Child indicates which finger was touched.	Yes. Errors on RH implicates left hemisphere and RH errors implicates right hemisphere.	Tactile perception discrimination and attention to tactile stimulation	Unilateral errors implicatecontralateral parietal lobe-can also occur with bilateral errors
Alertness and Concentration	Speech[a] sounds perception test	60 nonsense words presented on tape recorder. Child underlines correct sound from 4 alternatives	No	Attention Auditory discrimination cross-modal matching	Global anterior left-hemisphere deficits (Teeter, 1986)
	Rhythm[a]	Thirty pairs of rhythms are presented on tape recorder. Child writes S or D if pair is same or different.	No	Attention, auditory perception, and concentration	Global
Abstract reasoning logical analysis	Category test	80 items HINB, 168 items HRNB: Visual stimulus is projected on screen, and child selects one of four stimuli that corresponds to the original. If correct, bell rings. Incorrect: A buzzer sounds	No	Abstract concept formation, mental efficiency and flexibility, learning skills	Global Sensitive to right frontal lobe dysfunction in older children (Rourke et al., 1983)
	Trails B[a]	Series of circles alternating between letters (A–G) and numbers (1–8). Child connects circles alternating numbers-letters-numbers, etc.	No	Simultaneous processing, flexibility in planning	Global
Language	Aphasia screening test	HRNB items: Naming, drawing, reading, math, and spelling	Yes	Receptive language and expressive language, dyspraxia, word naming	Language items relate to left hemisphere. Constructional items related to right hemisphere reading, calculation, articulation, right/left discrimination
The following items are in HINB for younger children only:					
Visual-spatial	Matching pictures that are identical, then in same category	No	Perception generalization reasoning	Global	

Table 8.2 (continued)

Function	Subtest	Requirements	R/L Differentiation	Abilities	Localization
	Matching V's and figures, concentric square, and star	Matching group of figures, or group of V's of differing widths; copying complex concentric square and star	No	Visual-perception and motor abilities	Association areas
	Target test	Consists of large cardboard poster with nine printed dots. Examiner taps out a series of dots and after 3-second delay child reproduces series on protocol	No	Visual and spatial memory abilities	Association areas
Motor	Marching test	Child follows a sequence of circles connected by lines up a page touching each circle as quickly as possible, using right, left, and both hands	Yes	Gross motor function and coordination	Global
Alertness and concentration	Progressive figures	8 large shapes with small shapes inside. Child moves from the small shape inside to a large figure with same shape	No	Visual perception, motor speed, concentration, and cognitive flexibility	Global
Reason	Color form test	Geometric shapes of different colors on board. Child touches one figure then another, moving from shape-color-shape-color, etc.	No	Simultaneous processing and flexibility in planning	Global

Note: Reitan Indiana Neuropsychological Battery (HINB); Halstead-Reitan Neuropsychological Battery (HRNB).
[a]In HRNB for older children only.

benchmark for consideration as significantly below normal, and 1.5 standard deviations below the mean suggests mild impairment. While a normative approach may be essential for children in the five- to 15-year range, there are reasons to use caution with a Level of Performance analysis in isolation (Nussbaum & Bunner, in press). First, normal or abnormal levels of performance do not unequivocally confirm or disconfirm abnormal brain function (B. P. Rourke, 1981). Recovery of function may affect a child's level of performance such that a brain-injured child may reach normal performance. Other children may be falsely identified as neuropsychologically impaired as a result of other factors, including motivation, psychopathology or significant language deprivation (Teeter, 1986). Barron (2003) also suggests that there other factors that affect performance on these tests including a lack of motivation, inattention and low frustration tolerance. To be most reliable and valid, the Level of Performance approach should be used in conjunction with other interpretive factors.

Pathognomonic Sign Approach

One of the most common methods of analyzing neuropsychological data has been the deficit or pathognomonic sign approach. This approach was developed from research findings showing that certain items on neuropsychological batteries, particularly those items from the Aphasia Screening Test, occurred almost exclusively in brain-damaged individuals and not in normal individuals (Wheeler & Reitan, 1962).

The pathognomonic approach has been moderated by other findings demonstrating that false negatives can be common when this approach is used in isolation (Boll, 1974). Analyzing these signs is also particularly complicated in children because of wide developmental variations in acquiring some skills in typically developing children (Teeter, 1986). To be considered pathognomonic, it must be proved that the child at one time had acquired the skill prior to injury or insult. Although this is usually easier to establish in older children and adults, the pathognomonic sign approach is rarely advocated in isolation.

Pattern of Performance Approach

The differential score or Pattern of Performance approach involves developing an overall gestalt of the various performance patterns of the individual. In this method, the examiner builds a profile of individual strengths and weaknesses on test scores and begins to make inferences about the neuropsychological status of specific and global brain function based on these patterns. For example, a pattern of clear right-handed weaknesses on sensory and motor measures (e.g., elevated time for the right hand Tactual Performance Test (TPT) score and low tapping speed with the right hand), in conjunction with poor performance on the Speech Sounds Perception test and borderline Verbal Intelligence (IQ) scores (compared to normal Performance IQ), might suggest a pattern of left-hemisphere weaknesses. Reitan (1971) also reports that children and adults show similar patterns of performance on some tests: low scores on Part B of Trails compared to good scores on Part A has been found in individuals with left-hemisphere weaknesses, and poor performance on the Speech Sounds Perception Test is often found in individuals with left-hemisphere impairment.

Rourke, Bakker, Fisk, and Strang (1983) indicate that this method of interpretation is problematic for young, severely involved children. However, the Pattern of Performance approach has been broadly adopted by some neuropsychologists in their quest to identify meaningful subtypes of learning disabilities (Nussbaum & Bigler, 1986; B. Rourke, 1989).

Right-Left Differences

Reitan (1986a, 1987) suggests that Right-Left Differences can be a useful adjunct to understanding a child's neuropsychological performance. Table 8.3 reports right-left sensory and motor signs based on the Halstead-Reitan batteries for children. Reitan (1987) states that right-left indices can be a useful method for comparing the status of the two cerebral hemispheres, because even young children (5–8 years) have developed consistent hand preferences for simple motor tasks. Reitan (1987) further argues that right-left differences rely on "basic

Table 8.3 Right–left sensory and motor signs on the Halstead-Reitan neuropsychological test battery

Motor and sensory items	Left-Hemisphere signs[a]	Right-Hemisphere signs
Finger-tapping	Lower right hand tapping	Lower left hand tapping
Tactual performance test	Lower right hand scores	Lower left hand scores
Grip strength	Lower right hand scores	Lower left hand scores
Finger localization	Higher errors–right hand	Higher errors–left hand
Fingertip writing	Higher errors–right hand	Higher errors–left hand
Tactile perception	Higher errors–right hand	Higher errors–left hand

Note: Right-dominant individuals.
[a]Divide nondominant hand by dominant hand and subtract from 1. Use Neuropsychological Deficit Scale to determine significant differences between right and left hands.

neuroanatomical structure and organization rather than higher-level neuropsychological functions that have been developed through educational and environmental influences and experiences" (p. 6).

The extent to which right-left differences differentiate between brain-damaged and normal children is also of interest. Reitan (1987) found that this method of analysis had less overlap between a normal control group and children with brain damage when compared to the Level of Performance or the Aphasia Screening Test. Reitan also argues that it is important to identify children who lag behind in the basic biological organization of the brain (e.g., sensory and motor functions), which can be related to learning problems that may require remediation. Sensory and motor pathways are "essentially equivalent among younger children, older children and adults" (Reitan, 1987, p. 40). While the right-left approach can differentiate brain-damaged from normal children, it is not recommended in isolation or as a substitute for a comprehensive neuropsychological evaluation.

Neuropsychological Deficit Scale Approach

The Neurological Deficit Scale (NDS) incorporates a method for determining the child's Level of Performance, Right-Left Differences, Dysphasia and Related Deficits, and cutoff scores for differentiating brain-damaged from normal youngsters for each battery. The NDS also provides a total score for measuring the overall adequacy of neuropsychological functioning in children. Raw scores are weighted as Perfectly Normal (score = 0), Normal (score = I), Mildly Impaired (score = 2), or Significantly Impaired (score = 3) on the basis of normative comparisons. When using the NDS approach, the examiner takes the following steps: (1) converts raw scores on each test to corresponding weights (0, 1,2, or 3) based on normative tables provided by Reitan (1986a, 1987); (2) calculates right-left difference scores by dividing the score of the nondominant hand by that of the dominant hand, subtracting from 1.00, and converting to weighted scores; (3) makes clinical judgments following Reitan's (1984) guidelines for scoring the Aphasia Screening Test and assigns NDS scores; (4) totals weighted scores across each factor, Level of Performance, Right-Left Differences, and Aphasia Test, and (5) totals the weighted scores on 45 variables for older children and 52 variables for younger children to obtain a Total NDS Score. Reitan provides cutoff scores for brain-damaged versus normal children on the Total NDS score and for each of the factor scores.

Separate tables are available to analyze the neuropsychological test results of older children (Reitan, 1986a) and younger children (Reitan, 1987). Although the NDS approach seems to be an extension of an earlier standardized scoring procedure ("Rules for Neurological Diagnosis;" Selz and Reitan (1979a)), the normative group used to develop the weighted scores reported in the tables is not clearly described in recent test manuals available for the child batteries.

Several other methodologies use and interpret the Halstead-Reitan battery including the normative analysis, the biobehavioral, and the pragmatic approach. These approaches are briefly described.

Normative Analysis of the Halstead-Reitan Neuropsychological Tests

The normative analysis differs from the "level of performance" approach (+2 Standard Deviations above the mean) by analyzing scores on a continuum rather than cut-offs scores; brain damage is either present or absent. Clinicians use the meta-norms to determine a child's performance within a normative framework (Findeis & Wright, 1995) rather than as dichotomous criteria for determining brain damage versus no brain damage (Nussbaum & Bigler, 1997; Nussbaum & Bunner, 2008).

Biobehavioral Approach

The Biobehavioral Approach employs a broader, more comprehensive method for interpreting test data and was first proposed by Taylor and Fletcher (1990). This model assumes that neuropsychological functioning occurs with a context, with behavioral as well as neurocognitive, biological and genetic variables interacting and affecting how a disability is manifested (Nussbaum & Bunner, 2008). First, neuropsychological assessment includes information from four major sources: (1) presenting problems; (2) cognitive and psychosocial characteristics; (3) environmental, sociocultural and historical variables (e.g., family and school history), and (4) biological and genetic vulnerabilities (i.e., family history).

Second, the biobehavioral approach assesses other child and environmental factors that impact the child's basic neurocognitive functions in order to determine the intensity of the disability. These factors may also diminish the disability. Third, it is likely that an uneven profile of performance is associated with disabilities and it is critical to understand the variability to fully appreciate the nature of the disability. Fourth, the clinician must determine the impact of the environment on the neurocognitive functioning of the child. Fifth, neurocognitive deficits influence and ultimately limit the behavioral competencies of the child. These deficits are moderated by family and environmental factors. Finally, neurocognitive deficits must be interpreted within a developmental framework, and are considered correlational and not causal.

Pragmatic Approach

The Pragmatic Approach offers a more flexible model (Barron, 2003). Barron suggests a more fluid, non-battery approach for neuropsychological assessment. He advocates a tailored assessment of the child's strengths and weaknesses that can yield information for targeted interventions. Barron suggests other tests to assess a full spectrum of the child's assets and deficits.

Research Findings with CHRNB and HINB

While there have been relatively few studies on the CHRNB and HINB over the past decade, two studies are noteworthy. First, Vanderslcie-Barr, Lynch, and McGaffrey (2008) found that the screening batteries for the older and younger child produced a high percentage of correct classifications for determining normal or impaired function using archival data from a neuropsychological clinic. The authors found that the screening battery, neuropsychological deficit scale score (SBNDS) for older children had an 85 percent accuracy rate (cut-off scores 16/17), while a cut-off of 22/23 was 100 percent accurate for younger children.

Bello, Allen, and Mayfield (2008) investigated the sensitivity of the Children's Category Test level 2 (CCT-2) to determine brain dysfunction in children with attention–deficit hyperactivity disorder (ADHD) and children with structural brain damage. Although the Category test was found to be psychometrically sound, it did not differentiate children with brain damage from those with ADHD. The CCT-2 was not particularly sensitive to brain damage; further, both groups performed within the normal range. The authors conclude "we would recommend against the use of the CCT-2, including its factor and subtest scores, for clinical and research applications that aim to draw conclusions regarding the impact of brain injury on abstraction and problem solving abilities" (Bello et al., 2008, p. 338). They recommend using the longer version of the Category test within a comprehensive, larger battery.

Historically, studies utilizing the HRNB-OC and HINB have focused on the ability of these batteries either to distinguish between children with brain damage and those with learning disabilities, or to elucidate the profiles achieved by differing disorders (e.g., conduct disorder, psychiatric disorders). The longer Category test is the best discriminator for children with learning disabilities. Results of studies attempting to distinguish children with learning disabilities from those with brain damage and typically developing children suggest that children with LD have normal motor development with consistent weaknesses on the Category test (Shurtleff et al., 1988). Moreover, a relationship between reading and/or math difficulty and the Category test has been found (Shurtleff et al., 1988; Strom, Gray, Dean, & Fischer, 1987).

Intelligence scores show moderate correlations with the HRNB-OC (Shurtleff et al., 1988). In a review of studies that attempted to differentiate learning-disabled from brain-damaged children using the HRNB-OC, Hynd (1992) suggested that differential performance on intelligence tests may account for much of the ability of the HRNB-OC to discriminate between the two groups. On the other hand, Strom et al. (1987) found that the HRNB-OC provided unique data that were not redundant with data from the WISC-R. Because the issue of the overlap between the WISC-R and the HRNB-OC has not been resolved, it is important that the clinician recognize the overlap between the two measures and take intelligence into consideration when interpreting results.

In addition to the caution as to the influence of intelligence on performance on this battery, children with psychiatric disorders have also performed poorly on the HRNB-OC (Tramontana, Hooper, & Nardillo, 1988). The HRNB-OC's ability to distinguish children with psychiatric disorders from children with brain damage is not clear from existing research. This finding is consistent with the adult Reitan Battery, which also is not diagnostically specific for brain damage versus psychiatric disorder (Hynd & Semrud-Clikeman, 1992). The length and expense of the battery for general use with clients is another concern. The average amount of time to administer the battery ranges from six to 12 hours. Reitan (1986b) suggested that although reducing the length of the battery or developing a screening protocol would have value, the information necessary to answer referral questions makes the development of a screening protocol problematic. Alth-ough Reitan demonstrated a remarkable hit rate for his ability to determine brain damage (Selz & Reitan, 1979a, 1979b), there has not been sufficient documentation of the battery's ability to localize dysfunction or predict recovery from brain injury (Hynd, 1992). Furthermore, the HRNB-OC does not have adequate norms, and lacks detailed information on the validity and reliability of the battery.

Finally, the HRNB-OC requires intensive training for administration and interpretation of results, which also can be problematic for its use in general clinical or school environments. It may be more appropriate for general clinicians to use other measures to screen for possible neuropsychological involvement and to refer clients to a trained neuropsychologist for a full evaluation if areas of concern are identified. "In terms of future directions for the HRNB-OC and the RINB, if the HRNB-OC is to remain relevant and employed as a battery, then it should be updated with broader and more indepth measures, particularly in areas such as memory and attention" (Nussbaum & Bunner, 2008, p. 264).

Luria Theory of Neuropsychological Assessment for Children

Few would question the importance of the contributions made by the Russian neuropsychologist A. R. Luria, although some have been skeptical about the manner in which his clinical procedures have been standardized into a battery for assessing brain functions (Lezak, 1983). Luria originally described assessment procedures that varied from patient to patient depending on the specific brain area of concern. Attempts to standardize these procedures have been met with enthusiasm by some neuropsychologists and criticism by others. While the Luria-Nebraska Neuropsychological Battery for Children-Revised (LNNB-CR) was an attempt to standardize Luria's approaches, the battery is rarely used in clinical practice. Newer cognitive and neurocognitive assessment procedures represent innovative applications of Luria's conceptual model.

Luria's Conceptual Model

Luria (1980) described brain activity in terms of functional that incorporated elements of localization and equipotential theories. Localization theorists argued that specific brain regions were responsible for discrete brain functions with visual functions in the occipital lobe, auditory functions in the temporal lobe, and so on (Kolb & Whishaw, 2003). Equipotential theorists pointed out that complex human behaviors are controlled by functional CNS regions in such a way that when one portion is damaged, another adjacent or analogous region can assume its function (Kolb & Whishaw, 2003).

Luria's theory was different from other hypotheses at the time because he made four major assumptions:

1. Only specific parts of the brain (not all) are involved in forming a behavior.
2. No equipotentiality of brain tissue is hypothesized. Rather, brain tissue is conceptualized as being specialized for function, both psychologically and physiologically.
3. Behavior is conceived as a function of systems of brain areas working in concert rather than unitary and specific areas producing set behaviors. Therefore, a given behavior will be impaired when any part of the functional system responsible for the behavior is impaired.
4. Luria proposed that alternative functional systems exist—that is, a given behavior can be produced by more than one functional system. Therefore, the clinician will at times see no deficits when such deficits are expected given the locus of damage and at other times see deficits when no known damage is present. If the nature of the task is changed, then the locus of information processing will be changed and another input or output modality utilized. Thus, damage to areas controlling lower skills can be compensated for by areas controlling higher skills.

Research supports aspects of each of these theories in various degrees because functions appear localized to some extent; however, a particular behavior may be impaired because of damage to a number of different brain areas. Kolb and Whishaw (2003) suggest that the important questions center on how damage to a particular site can affect specific behaviors or performance. Luria's functional systems approach conceptualizes brain function as follows. Luria (1980) discussed three functional units as: (1) the arousal unit; (2) the sensory receptive and integrative unit, and (3) the planning, organizational unit (see Table 8.4). The nature of each functional unit is briefly described.

Functional Unit I

In Luria's theory (1980) the arousal system is the first unit and comprises the reticular activating system (RAS), the midbrain, the medulla, the thalamus, and the hypothalamus. Visual, auditory, and tactile stimulation comes through this unit to higher cortical regions. The structures work together in concert in Unit I to regulate energy level and to maintain cortical tone. This unit raises or lowers cortical arousal depending on internal needs. When cortical tone is too low, the brain loses its ability to discriminate between stimuli. Another function of this unit is to filter out irrelevant stimuli. The RAS prevents the cortex from being flooded by unimportant stimuli that could interfere with cortical functioning. If the RAS filters out too much stimulation, sensory deprivation and hallucinations may be present as the cortex attempts to generate its own activity to keep itself aroused. Severe injury to Unit I can result in marked deterioration of wakefulness, with loss of consciousness and possible death. Less severe injury can result in disorganization of memory, distractibility, attentional problems and insomnia. If Units II and III are functional, then in later development or in adulthood these units can assume the functions of Unit I and monitor hyperactive and/or impulsive behavior. Methylphenidate has also been found to activate Unit I and thereby decrease behaviors of impulsivity and poor attention.

Functional Unit II

Unit II is considered the sensory system and consists of the parietal, temporal, and occipital lobes; its major function is sensory reception and integration. Therefore, the areas of Unit II correspond to their sensory modality (temporal for auditory, parietal for sensory

Table 8.4 Selected research with the Halstead-Reitan neuropsychological batteries

Reference	Population	Age	Major findings
Batchelor and Dean (1993)	Learning	9–14 years	1. Two distinct clusters across ages. Group 1 = diffuse deficits. Group 2 = spatial memory deficits. 2. Diffuse deficits may not change with age. 3. Specific deficits deem to change with age.
Berman and Siegal (1976)		CD, normal	1. CD > normals on every HRNB task. 2. CD lowest on verbal mediation, concept formation, and perceptual.
Boyd, Tramontana, and Hopper (1986)	Psychiatric	9–16 years	1. DE = WISC-R + Aphasia test. 79% rate for prediction. LNNB-C status. 2. DE valid as screening device.
Coutts et al. (1987)	LD, non-LD	11–12 years	1. LD > non-LD on Category test. 2. Minimal practice effect after 3 weeks for LD. 3. Category test may be useful for measuring treatment efficacy.
Gamble, Mishra, and Obrzut (1988)	Referred-learning	6–8 years	1. Category test loaded on psychomotor Speed Factor. 2. TPT loaded on Memory Factor. 3. Use Reitan-Indiana with caution with young LD children.
Newby and Matthews (1986)	Clinic-referred	6–14 years	1. Specific neuropsychological function not predicted by PIC.
Nussbaum et al. (1988)	Referred-learning	7–12 years	1. Anterior deficits related to Social Withdrawal Aggression, Hyperactivity, and Externalized scales on CBCL. 2. Posterior deficits high on ANX.
Reitan and Boll (1973)	Normal, MBD, BD	5–8 years	1. BD > MBD > normals. 2. 84%overall accuracy rate classification. 3. 96% BD, 89% MBD, 64% normals.
Selz and Reitan (1979a)	Normal, LD, BD	9–14 years	1. LD normal on motor tasks. 2. LD similar to BD on cognitive and attentional tasks. 3. 80% accuracy, error-impaired groups as less impaired.
Selz and Reitan (1979b)	Normal, LD, BD	9–14 years	1. Classification rules. 2. BD < LD > normals performance. 3. 73% accuracy rate for classification.
Shurtleff, et al. (1988)	Learning	10–12 years	1. Low to moderate correlations of HRNB and WISC-R. 2. Speech Sounds related to Reading decoding and spelling. 3. Category related to math.
Strang & Rourke (1983)	LD	9–14 years	1. Low math/normal reading/spelling group scores low on Category, bilateral tactile-motor, and visual-perceptual-organization.

Table 8.4 (continued)

Reference	Population	Age	Major findings
			2. Low math related to low reasoning and sensory-motor.
Strom et al. (1987)	LD	11 years	1. 28% variance in reading accounted for by HRNB. 2. 15% variance in math accounted for by HRNB. 3. Unique contributions of HRNB not measured by WISC-R.
Teeter (1985)	Normal	5—8 years	1. RINB accurate for discriminating high, average, and low readers. 2. RINB more predictive than McCarthy Scales for spelling, reading, and math. 3. Predictive variable stable over two years.
Tramontana et al. (1980)	Psychiatric	9—15 years	1. 60% mild impairment on HRNB using Selz and Reitan rules. 2. 25% moderate impairment. 3. Impairment > chronic psychiatric.
Tramontana and Hooper (1987)		CD, depression	1. No distinct neuropsychological features for INT and EXT disorders.
Tramontana and sherrets (1985)		Psychiatric	1. 50% abnormal HRNB or LNNB-C 2. Impairment > young boys with chronic psychiatric history.
Tramontana, Hooper, and Nardillo (1988)	Psychiatric	8—16 years	1. Impairment > with more severe behavior problems. 2. Mostly in young children with INT disorders. 3. EXT disorders no distinct neuropsychological features.

Notes: BD = brain damaged; MBD = minimal brain dysfunction; LD = learning-disabled; CD = conduct-disordered; RINB = Reitan Indiana Neuropsychological Battery; HRNB = Halstead-Reitan Neuropsychological Battery; LNNB-CR = Luria Nebraska Neuropsychological Battery for Children-Revised; INT = Internalized Scale on the Child Behavior Checklist; EXT = Externalized Scale on the Child Behavior Checklist.

tactile, and occipital for vision). Unit II has been hypothesized to be guided by three functional laws: (1) hierarchical structures of cortical zones do not remain the same during ontogenesis; (2) hierarchical zones decrease in their specificity of function with development, and (3) progressive lateralization of function within hierarchical zones in-creases with development (Luria, 1980). This hierarchy is further divided into three zones: primary, secondary, and tertiary. The primary zones are responsible for sorting and recording sensory information. The secondary zones organize the sensory information and code it for later retrieval. The tertiary zones combine data from various sources in order to lay the basis for organized behavior.

Primary Zones

The primary zones generally consist of sense receptors with point-to-point relationships to the peripheral sense organs. These zones are predetermined by genetics and are the most hardwired of the areas. The primary auditory zone is in the temporal lobe and involves auditory perception. The primary tactile zone is in the sensory strip of the parietal lobe and involves tactile perception. Finally, the primary visual zone is in the occipital lobe and involves visual perception.

Secondary Zones

The secondary zones are generally involved in input of data and integration of information. These zones process information sequentially and have a link, with more than one stimulus being received by the brain at a time. For the auditory secondary zone, the locus is in the secondary regions of the temporal lobe and involves the analysis and synthesis of sounds and the sequential analysis of phonemes, pitch, tone, and rhythm. The secondary tactile zone is in the parietal lobes next to the sensory strip and is involved in two-point discrimination, movement detection, and recognition of complex tactile stimuli (i.e., identifying shapes by touch). The secondary visual zone surrounds the primary visual center of the occipital lobe and is involved in visual discrimination of letters, shapes, and figures.

There is specialization in the secondary zones, with the left hemisphere predominantly responsible for analyzing verbal material and language while the right hemisphere is important for the analysis of non-verbal material such as music, environmental sounds, and prosody of language. Both hemispheres play a role in reading, with the right hemisphere important for recognizing unfamiliar shapes. Once words and letters have been learned, recognition of these shapes becomes a process of the left hemisphere. Both hemispheres are involved in comprehension, with the left hemisphere more involved with semantic and syntactic analysis and the right hemisphere with processing the emotional quality and tone of the passage. Lateralization of function is also found for writing, with the right hemisphere activated primarily when the task is a novel visual-motor task and the left hemisphere activated primarily once a task is learned.

Intelligence tests are hypothesized to measure Unit II functions. Given that Unit II is the center for the analysis, coding, and storage of information, damage to this region results in difficulty in learning basic reading, writing, and mathematics skills.

Tertiary Zones

Tertiary zones allow for cross-modal integration of information from all sensory areas. Information is processed simultaneously and involves integration of various modalities. For example, the reading process is an integration of auditory and visual material; language is an integration of grammatical skills, analysis of auditory information, and comprehension of auditory material, and mathematics involves the integration of visual material with knowledge of number and quantity. These zones are the primary region that intelligence tests are thought to directly measure. Damage to this association area can result in a lowered IQ score, poor reading, writing, and mathematics ability, and language comprehension.

Functional Unit III

Unit III is responsible for output and planning. It is located in the frontal lobes which are further demarcated into three hierarchical zones. The primary zone, in the motor strip of the frontal lobe, is concerned with simple motor output. The secondary zone, in the primary premotor regions, is involved in sequencing motor activity and speech production. The tertiary zone located in the orbitofrontal region of the frontal lobe (the prefrontal region) is the last region to myelinate and develop. Development continues until the third decade of life. The tertiary zone of Unit III is primarily involved with planning, organization, and evaluation of behavior, functions similar to the executive functions. Damage to this area has been linked to problems in delaying gratification, controlling impulses, learning from past mistakes in behavior, and focusing attention. In many cases damage to this zone can be difficult to distinguish from psychiatric and behavior problems. When dysfunction occurs in Unit I, later development of Unit III can compensate or modulate levels of arousal. Moreover, Unit III can activate other parts of the brain and has rich connections to all regions of the brain.

Developmental Considerations

Luria's conceptual framework is based on the theory that certain skills are acquired at different rates depending on the neurodevelopmental stage of the child (Golden, 1981). Further, specific problem solving strategies, behaviors, and skills are dependent on biochemical as well as physiological maturation, including myelination and the growth of cells, dendritic networks, and interconnecting neuronal pathways. Although physiological development is related to psychological maturation, this relationship can be altered by adverse environmental events. Table 8.5 outlines the five major developmental stages described by Golden (1981).

Injury during any one of these stages is thought to produce various deficits depending upon the site and severity of injury. Golden (1981) suggests that damage to the developing brain during Stage 1 is likely to produce deficits in arousal and that, when severe damage ensues, death or mental retardation may result. Damage after 12 months of age is less likely to produce attentional deficits, although physiological hyperactivity is associated with damage prior to 12 months. Paralysis, deafness, blindness, or tactile deficits may result from unilateral injury to the primary sensory areas during Stage 2 development. In some instances, sensory or motor functions may be transferred to the opposite hemisphere if damage occurs during this stage. Although damage after this developmental stage is likely to produce more serious deficits, there are still compensatory factors that play a role in recovery of function. Golden cautions, however, that bilateral damage is more serious, producing deafness, blindness, and/or paralysis, where compensation is less likely. During Stage 3 development, the two hemispheres begin to show differentiation of function in terms of verbal and nonverbal abilities (Golden, 1981). Unilateral damage is likely to result in loss of language functions if injury is sustained in the left hemisphere once verbal skills are present, at about the age of two years. Damage prior to age two may result in transfer of language to the right hemisphere, whereas damage after age two begins to mimic recovery of functions similar to what is seen in adults (Golden, 1981). However, Golden (1981) suggests that plasticity (i.e., transfer of function) is less likely when injuries are diffuse in nature, or in cases of mild injury. Thus, small injuries early in development can have more deleterious effects than larger injuries later in life. Recovery of function will be explored in more detail in later chapters.

Golden (1981) suggests that learning during the first five years of life is primarily unimodal in nature, with little cross-modal, integrative processing. Early reading during this stage is characterized by rote strategies involving memorization of individual letters, words, or letter sounds. The visual symbol is meaningful only in its relationship to spoken language. Cross-modal learning is possible during Stage 4 when tertiary association regions of the sensory cortices are developing. Injury to these association regions can result in significant learning impairments, such as mental or cognitive deficits or learning disabilities. The type of deficit depends on the location and severity of the injury, and even small insults can affect the integration of one or more sensory modalities (Golden, 1981). Golden (1981) suggests that injuries to tertiary regions are not always evident until Stage 4 development. Injury in one stage may not produce observable deficits until a later stage because the brain regions subserving specific psychological and behavioral functions are not mature. For example, a child sustaining injury to

Table 8.5 Major systems and behavioral correlates of Luria's functional Units

Functional system	Brain units	Behavioral correlates
Unit 1: Arousal System	Reticular activating system pons and medulla through thalamus to cortex	Modulate cortical arousal
		Filters incoming stimuli
		Attention and concentration
Unit 2: Sensory System	Primary temporal lobes	Auditory perception
	Secondary temporal lobes	Analysis and synthesis acoustic sounds and sequential analysis
		Phoneme, pitch, tone, and rhythm
	Primary parietal lobes	Tactile perception
	Secondary parietal lobes	Two-point discrimination
		Movement detection
		Recognition of complex tactile stimuli (e.g., shapes)
	Primary occipital lobes	Visual perception
	Secondary occipital lobes	Visual discrimination (letters, shapes, etc.)
		Cross-modal integration
	Tertiary parital occipital/temporal region	Simultaneous processing
		"Intelligence" (e.g., reading, writing, math, language, syntax, grammar, stereognosis, spatial rotation, angle discrimination)
Unit 3: Output/ Planning	Primary frontal lobes	Simple motor output
	Secondary frontal lobes	Sequencing motor activity
		Speech production
	Tertiary frontal lobes	Decision making and evaluation
		Impulse control
		Delay of gratification
		Focused attention

tertiary regions at the age of two may appear normal at age three, but may show serious learning deficits at age 10 (Golden, 1981). Golden further indicates that predicting future deficits is complicated by these neurodevelopmental factors, and that neuropsychologists must consider these issues when injury is sustained early in life. Finally, according to Golden (1981), Stage 5 involves the development of the prefrontal regions of the brain, which begins during adolescence. According to this neurodevelopmental theory, deficits resulting from injury to frontal regions may not begin to emerge until 12–15 years of age or later. Others have argued that frontal lobe development may occur at earlier stages than suggested by Golden (1981). For example, Becker, Isaac, and Hynd (1987) and Passler, Isaac, and Hynd (1985) describe a progression of frontal lobe development beginning at age six. In these studies it was found that some tasks thought to be mediated by the frontal lobes begin at six years of age (e.g., flexibility during verbal conflict tasks), continue to emerge at age eight (e.g., inhibition of motor responses), and still are incomplete at age 12 (e.g., verbal proactive inhibition). Neurodevelopmental stages are of primary importance in child neuropsychology, and further research is needed to more clearly map these stages of brain development. Although the question of frontal lobe development will be of continued interest to researchers and clinicians in the next decade, the relationship between brain development and psychological and behavioral function has a strong empirical base.

Although the Luria-Nebraska Children's Battery Revised (LNCB-R) was designed to assess brain functioning based on Luria's model, the test has not been adequately researched. Attempts to standardize and validate the LNCB-R have been slow and "the lack of current research findings present a major concern" (Leark, 2003, p. 155). "Several contemporary neuropsychological assessment tools are available to assess skills similar to those tapped by the Luria-Nebraska domains and were designed solely for children" (Hale & Fiorello, 2004, p. 137). There are several newer batteries that were developed using Luria's conceptualizations of brain functions. The NEPSY and the Cognitive Assessment System (CAS) will be briefly reviewed next.

NEPSY: A Developmental Neuropsychological Assessment

The NEPSY, first developed in 1998 (Korkman, Kirk, & Kemp, 1998), has been revised (Korkman, Kirk, & Kemp, 2007). The NEPSY-II assesses complex cognitive functions as well as subcomponents across functional domains. The instrument is designed to assess neuropsychological development in preschool and school-aged children (ages 3–16 years) including children with Attention-deficit Hyperactivity Disorder, Autism and Asperger's disorder, emotional disturbance, deaf and hearing impaired, language disorders, intellectual disabilities, math and reading disabilities, and traumatic brain injury. Clinicians may use the NEPSY-II for the following: to assess the neurocognitive development of children; to create a tailored assessment to answer specific referral questions, and to diagnose various disorders and to develop intervention plans (Korkman et al., 2007).

Six major domains are measured including: Attention and Executive Functioning, Language, Memory and Learning, Sensorimotor, Social Perception, and Visuospatial. See Korkman et al. (2007) for an in-depth description of the subtests for each domain.

Attention and Executive Functioning

The Attention and Executive Function Scale measures inhibition of learned and automatic responses, monitoring and self-regulation, vigilance, selective and sustained attention, nonverbal problem solving, planning and organizing complex responses, and figural fluency.

Language

The Language Scale measures major phonological processing, repetition of nonsense words, identification of body parts, verbal semantic fluency, rhythmic oral sequences, and the comprehension of oral instructions.

Memory and Learning

The Memory and Learning Scale measures immediate memory for sentences; narrative memory and free recall, cued recall and recognition recall; recall with interference, and immediate and delayed memory for designs, faces and lists.

Sensorimotor

The Sensorimotor domain measures hand movements, repetitive finger movements, and use of a pencil with speed and precision.

Social Perception

The Social Perception domain measures facial affect recognition, comprehension of others' perspectives, and intentions and beliefs.

Visuospatial

The Visuospatial domain measures line orientation, copying geometric figures, three-dimensional designs, mental rotation of objects, whole-part relations, and schematic map reading.

Research Findings with NEPSY

Korkman (1999) provides a nice review of validity studies with the NESPY. Specifically the NEPY appears to have validity for differentiating subtypes of learning difficulties, discriminating ADHD from other learning disabilities, and identifying deficits in infants with prenatal alcohol exposure. Further, Korkman reports that children with brain damage had deficits on the NEPSY, but did not have lateralizing effects. This is consistent with findings that children show functional reorganization of the brain with early brain damage, and that children tend to have more diffuse rather than focal brain dysfunction.

The NEPSY can also be used to identify neurodevelopmental deficits in a number of clinical populations. Mikkola et al. (2005) found that extremely low birth weight (ELBW) infants had decreased performance on measures of the NEPSY (i.e., Attention, Language, Sensorimotor, Visuospatial, and Verbal Memory) compared to controls. Shum, Neulinger, O'Callaghan, and Mohay, (2008) also reported poor performance on verbal memory and attention on the NESPY and low scores on the Trail Making B test. These problems were associated with parent and teacher ratings of attentional difficulties. Young children at risk for ADHD were also found to have deficits on NEPSY measures of executive tasks [e.g., Attention, Fluency (Perner, Kain, & Barchfeld, 2002)

CAS: Cognitive Assessment System

The Cognitive Assessment System (CAS) was designed to assess the cognitive functioning of children 5–18 years of age (Naglieri & Das, 1997). The CAS was developed to identify specific cognitive problems underlying learning and attentional difficulties. The authors indicate that the CAS has utility for assessing cognitive and neuropsychological functions from multiple dimensions or domains, differential diagnosis for learning and attentional difficulties, and intervention planning. The CAS is theory-driven, based on neuropsychological and cognitive theories—Luria's model and the PASS model. The PASS theory suggests that four basic functions underlie cognitive functions including planning, attention, successive and simultaneous processes.The CAS has strong psychometric properties (Naglieri & Das, 1997; Strauss et al. 2006).

Planning

The Planning scale measures mental processes for determining, selecting, applying, and evaluating problems. Performance on this scale is dependent on retrieval of knowledge and impulse control, and is reflective of prefrontal lobe functions.

Attention

The Attention scale measures selective focus on stimuli, while inhibiting other responses. Selective attention, focused cognitive activity, resistance to distractions, orienting to tasks, and vigilance reflect reticular activating system functions.

Simultaneous

The Simultaneous scale measures the ability to perceive and integrate parts into a whole or group. The parietooccipital regions are primarily involved with this mental process.

Successive

The Successive scale measures the ability to integrate stimuli in a sequential, serial order.

Research Findings with CAS

The CAS appears to have been well conceived and researched. While initial factor analyses support the four-factor solution of the PASS model (Naglieri & Das, 1999), others have not found the same results (see Strauss et al., 2006 for a review).Research has shown that the CAS has utility for measuring cognitive processing deficits in clinical groups including children with reading difficulties (Joseph, McCachran, & Naglieri, 2003), children with written expressive disorders (Johnson, Bardos, & Tayebi, 2003), children with ADHD (Naglieri &

Das, 2005), and children with moderate to severe TBI (Gutentag, Naglieri, & Yeates, 1998).The following results have been reported: (1) Children with ADHD had lower scores on the Planning scale of the CAS compared to children without ADHD; (2) the Planning scale best discriminates children with and without written expressive disorders, and (3) children with TBI show low scores on the Planning and Attentions scales.

The CAS is correlated with achievement measures, other intelligence and neuropsychological tests, including the NEPSY (Naglieri, DeLauder, Goldstein, & Schwebach, 2005; Naglieri & Bornstein, 2003). Specifically, low scores on the Successive Processing scale is related to poor reading scores, while low Planning scores are related to decreased performance on calculation, dictation and writing scores on the WJ-R (Naglieri & Bornstein, 2003)

Neuropsychological Protocol: Austin Neurological Clinic

Nussbaum et al. (1988) describe a neuropsychological protocol that reflects neurobehavioral functioning along an anterior/posterior (AP) axis or gradient. This framework is formulated on the anatomical divisions of the cortex along the frontotemporal and parietooccipital axis. Frontal (A) regions have been associated with motor, attentional, sequential processing, reasoning, and abstract thinking abilities, while parietotemporal (P) regions have been associated with tactile, visual perceptual, word recognition, and spelling functions (Nussbaum et al., 1988). On the basis of theoretical and research findings with children and adults, Nussbaum et al. (1988) have included test items from the Halstead-Reitan battery (i.e., finger tapping, tactual performance test, sensory perceptual exams); the Benton Visual Retention Test (BVRT); the Kaufman Assessment Battery for Children (K-ABC) (i.e., Number Recall, Word Order, Gestalt Closure, and Spatial Memory); the Wechsler Scales for Children-Revised (WISC-R) (i.e., Similarities, Digit Span), and the Wide Range Achievement test (WRAT). See Table 8.6 for a detailed description of Anterior and Posterior measures. While Nussbaum et al. (1988) recognize that this conceptualization is somewhat artificial, they provide this model for heuristic purposes and discuss the importance of developing models to investigate functional asymmetries in children with various learning and personality disorders. Initial findings with the A/P model suggest that children with weaknesses on anterior measures are likely to exhibit psychological and behavioral problems. These findings may be important for clinicians when developing behavioral management interventions.

Boston Process Approach

The Boston Hypothesis Testing Approach utilizes an initial cadre of tests to sample specific behaviors, including memory, language, visual-motor skills, and attention. From these measures, additional tests may be added to further evaluate areas of possible deficit.

The Boston Process Approach is not a published approach and can vary depending on the clinician. It is also called the Boston Hypothesis Testing Approach. The approach suggests that basic areas of functioning are screened and from this screening hypotheses are developed and additional measures are added (Lezak, 1983; 1995). The Boston Process Approach has its foundation in the belief that both the qualitative nature of behaviors and the quantitative scores are important in order to understand the client's deficits and to develop the treatment programs (Kaplan, 1988).

The Boston Process Approach emphasizes the utilization of information about the client's age, handedness, and previously developed skills, which is gathered through the interview process. Such information not only informs the conduct of the evaluative process, but also puts into focus how these skills are affected or spared from brain damage. In addition, these skills are assessed to determine which strategies the client may employ to compensate for his or her impairments. Emphasis is also placed on "testing the limits"-that is, asking the client to answer questions above the ceiling level. Because

Table 8.6 Austin neurological clinic: a paradigm of anterior/posterior measures

Neuropsychological measures	Anterior function assessed
Finger oscillation, dominant and non-dominant hands	Fine motor coordination
Similarities-WISC-R	Verbal abstract reasoning, cognitive flexibility
Digit span-WISC-R	Sequential processing, attention, cognitive flexibility
Number recall-K-ABC	Sequential processing, attention
Word order-K-ABC	Sequential processing, attention
Tactual performance test (TPT)-both hands[a]	Motor coordination
	Posterior function assessed
Sensory perceptual exam	
Tactile	Tactile perception
Visual	Visual perception
Finger recognition	Tactile gnosis
	Sensory integration
Fingertip Number writing	Tactile graphesthesia, Sensory integration
TPT-both hands[a]	Tactile perception, Spatial abilities, Sensory integration
TPT memory	Memory for tactile information
TPT localization	Spatial memory
Testalt closure-K-ABC	Simultaneous visual processing, Figure-ground discrimination
Spatial memory-K-ABC	Visuospatial memory
Wide range achievement test	
Reading	Reading recognition skills
Spelling	Spelling skills

[a]The TPT for Both Hands is included in the Anterior composite score when the TPT-Both Hands is impaired, and when the Sensory Perceptual Exam (SPE) and the Benton Visual Retention Test (BVRT) are in the normal range. The TPT for Both hands is included in the Posterior composite score when the TPT-Both Hands is impaired, and when the SPE and the BVRT are impaired.

Source: Adapted from *Archives of Clinical Neuropsychology*, Vol. 3, N. L. Nussbaum, E. D. Bigler, W. R. Koch, J. W. Ingram, L. Rosa, and P. Massman, "Personality/Behavioral Characteristics in Children: Differential Effects of Putative Anterior versus Posterior Cerebral Asymmetry," pp. 127–135, copyright © 1988, with kind permission from Elsevier Science Ltd., The Boulevard, Langford Lane, Kidlington 0X5 1 GB, UK.

patients with brain damage are often able to do difficult tasks past their ceiling level (Milberg & Blumstein, 1981), it is important to determine these limits through testing to verify if the failure lies in the client's inability, retrieval problems, or less efficient strategies due to brain damage. This modification is important not just for verbal tasks, but also for timed performance tasks. On these timed tasks it is important to determine whether the problem is one of power (mastery) or speed.

A process approach allows flexibility in assessment with an eye to how this assessment informs the treatment plan. Kaplan (1988) suggests that the process approach is helpful to provide insights into brain-behavior relationships. Both standardized and experimental measures are utilized. Therefore, the goal of the process approach is to evaluate the current behavioral functioning in light of intuited brain-behavior relationships.

Instruments utilized in the Boston Process Approach are described in the following section; they include tests of reasoning, verbal language and memory, and perception. See Table 8.7.

Table 8.7 Neuropsychological test procedures: modified boston battery

History
Neuropsychological screening examination
Wechsler intelligence scale for children—3rd edition
Symbol digit modalities test (optional if digit symbol not used)
Wisconsin card sorting test
WRAML
Rey auditory verbal learning test
Neuropsychological screening test
Boston naming test
Rey-Osterreith complex figure
Finger tapping test
Hooper visual organization test
Wide range achievement Test-revised (optional)

Note: September 1986.

Tests of Reasoning

Stroop Color Word Test

The Stroop consists of 100 words (random color names) printed in three different colors. In separate trials, the child will be asked to read the color word (maybe printed in a different color) and then call out the color (maybe a different color word). The time taken to read the color words is usually recorded. Young ADHD children had trouble inhibiting habitual responding on this task (Boucugnani & Jones, 1989).

Wisconsin Card Sorting Test

The Wisconsin Card Sorting Test (WCST) was developed as a measure of frontal lobe dysfunction. The child must match 128 cards to four key cards on the dimensions of color, form, or number. The criteria for correct responses change unexpectedly, and the child must alter the response pattern. Several scores can be derived from the test, including the total number of errors and the number of perserverative errors. Heaton, Chelune, Talley, Kay, and Curtiss (1993) provide a revised and expanded manual for the WCST, with extensive norms for children and adolescents. The WCST measures reasoning, concept formation, and flexibility, and has been shown to be sensitive to frontal lobe activity in children (Chelune, Fergusson, Koon, & Dickey, 1986).

WRAML

The Wide Range Assessment of Memory and Learning (WRAML) contains a Screening Index for memory and new learning ability. This screening index includes the ability to scan pictures and then recall items that have been changed. In addition, the child is shown four pictures of increasing complexity and, after a 10-second delay, is asked to reproduce the figure. The screening index also includes a measure of verbal learning. This subtest requires the child to learn a list of simple words within four trials. This test yields a learning curve over trials. The child then goes on to an additional test with delayed recall of this list following the intervening task. Finally, the child is read two stories and is asked to recite the stories back to the examiner. The child is asked to recall these stories after an intervening task. An optional story recognition format presents the details from a story in a multiple-choice manner. Children who are unable to recall story details spontaneously may be able to elicit this information from memory when prompts are provided.

Rey-Osterreith Complex Figure Test

The Rey-Osterreith Complex Figure Test was standardized by Osterreith in 1944. This task requires the child to copy a complex figure using six different colors: red, orange, yellow, blue, green, and purple. Every 45 seconds, the child is asked to switch colors. If the child completes the figure before using all colors, the examiner notes the final color utilized and the time needed. After 20 minutes, the child is asked to draw the figure from memory.

Tests of Verbal Language and Memory

Boston Naming Test

The Boston Naming Test (BNT), developed by Kaplan, Goodglass, and Weintraub (1978), requires the child to name increasingly difficult black and white pictures. If the child misperceives or fails to recognize a picture, he or she is given a cue as to a category (i.e., if a banana is called a "cane," the examiner might say, "No, it's something to eat"). Phonemic cues are also provided by giving the child the beginning sound of the target word. This cue is given after an incorrect response or no response. Norms for children are being developed for this test, but remain incomplete at this time. The BNT has successfully differentiated children with reading problems from those without (Wolf & Goodglass, 1986) Results from children with language disorders found their performance to be similar to that of children with learning disabilities (Rubin & Liberman, 1983). McBurnette et al. (1991) also found that males with conduct disorders show significantly discrepant scores on this measure, suggesting that these children have verbal expressive disabilities. A total error score can be derived for this instrument.

Controlled Oral Word Association Test

The Controlled Oral Association Test (COWA) requires the child to say as many words beginning with the letter "F" as he/she can think of within one minute; then words beginning with "A," the "S." These letters were selected by how frequently they appear in the English language. This test is sensitive to brain dysfunction in adults, particularly in the left frontal region, followed by the right frontal area (Lezak, 1994).

California Verbal Learning Test

The California Verbal Learning Test-Children's Version (CVLT-C) was developed to assess memory-related strategies and processes for verbal material for children five to 16 years of age (D. C. Delis, Kramer, Kaplan, & Ober, 1994). The test was developed as an adjunct to intellectual and neuropsychological evaluations for children with learning, attentional, intellectual, psychiatric, and other neurological disorders. The test measures memory and verbal learning skills using a hypothetical shopping list in an effort to use everyday, meaningful stimuli. Learning strategies, learning rate, interference (proactive and retroactive conditions), memory enhancement using cuing, and short and longer delay retention are variables of interest in the CVLT-C.

The CVLT-C comprises the following subtests: List A, Immediate Free-Recall; List B, Immediate Free-Recall; List A, Short-Delay Free-Recall; List A, Short-Delay Cued-Recall; List A, Long-Delay Free-Recall; List A, Long-Delay Cued-Recall, and List A, Long-Delay Recognition. The Test Manual presents normative data; a description of the standardization group; administration, scoring, and interpretation guidelines, and reliability and validity studies with the CVLT-C. Nine-hundred-twenty children were selected from a representative sample across gender, racial, and age categories using U.S. Bureau of Census data.

Initial research suggests that the CVLT-C has adequate reliability and validity (D. C. Delis et al., 1994). The CVLT-C could be used to investigate memory and verbal learning abilities of children with various disorders, including Down syndrome and fetal alcohol syndrome (FAS) (Mattson, Riley, Delis, Stern, & Jones, 1996), ADHD (Loge, Staton, & Beatty, 1990), developmental verbal learning disability without ADHD (Shear, Tallal, & Delis, 1992), and dyslexia (Knee, Mittenburg, Bums, DeSantes, & Keenan, 1990). Developmental differences appear on the use of semantic clustering (Levin et al., 1991) and on beginning (primacy) and ending (recency) portions of the lists. Learning curves (average number of words learned across five trials) also were found to differ across ages, with older children displaying steeper curves than younger children (D. C. Delis et al., 1994). Finally factor analysis yielded six major factors that appear consistent with the theoretical principles of the CVLT-C. The factor structure is also similar to the solution found on the Adult CVLT.

At present, the CVLT-C appears psychometrically sound and measure skills not readily measurable with other neuropsychological tests.

Neurosensory Center Comprehensive Examination for Aphasia

The Spreen-Benton Aphasia Tests or the Neurosensory Center Comprehensive Examination for Aphasia (NCCEA) comprises 20 subtests measuring language functions, and four subtests measuring visual and tactile skills (Spreen & Benton, 1969). Spreen and Benton (1977) describe the revised NCCEA tests in detail and list the following tests for the language domain: Visual Naming, Description of Use, Tactile Naming (right hand), Tactile Naming (left hand), Sentence Repetition, Repetition of Digits, Reversal of Digits, Word Fluency, Sentence Construction, Identification by Name, Identification by Sentence (Token Test), Oral Reading (Names), Oral Reading (Sentences), Reading Names for Meaning, Reading Sentences for Meaning, Visual-Graphic Naming, Writing Names, Writing to Dictation, Writing from Copy, and Articulation. The NCCEA items cover a range of language functions and were selected to be sensitive to aphasic symptoms, but not to mild intellectual impairment.

Tests of Perception

Hooper Visual Organization Test

The Hooper Visual Organization Test is comprised of 20 cut-up pictures that the subject is asked to write or name. The test has been shown to be related to frontal lobe functioning in children (Kirk & Kelly, 1986). A total accuracy score can be derived.

Benton Visual Perceptual Tests

The Benton Visual Retention Test, the Benton Facial Recognition Test, the Benton Judgment of Line Orientation Test, and the Benton Visual Form Recognition Test can be used as part of a larger, more comprehensive battery for children between the ages of six and 14 years. Hynd (1992) suggests that the Facial Recognition and the Line Orientation tests may be most useful clinically.

Judgment of Line Orientation

The Judgment of Line Test requires the child to estimate the relationship between line segments by matching a sample to an array of 11 lines in a semicircular array of 180". The test includes 30 items, with five practice items to teach the test. There are two forms, H and V, which present identical items in different order.

Test of Facial Recognition

This test requires the child to match faces with three different conditions: identical view orientation, matching front view with three-quarter views, and front view with lighting differences. The first six items require a match of only one pose with six selections. The final 16 items require the child to match three selections to the sample. This test is sensitive to language comprehension difficulties as well as to visual-spatial processing problems.

Cancellation Tasks

The Cancellation Task requires the child to select a target visually and repetitively, as quickly as possible. One task that may be used (D2 task) requires the child to cross out all the Ds with two marks above them. There are 15 lines of Ds, and the child is asked to cross out the Ds in each line for 20 seconds and then to switch to the next line. Lower scores may indicate problems in visual scanning, inhibition problems, and inattention.

Clients with difficulties in sequencing and inattention do poorly on this task compared to those individuals without these problems (Spreen & Strauss, 1991; Sohlberg & Mateer, 1989). The Symbol Search task from the WISC-III and the Visual Matching and Cross-Out Tasks from the Woodcock-Johnson are additional tasks that require quick visual scanning and attention to task, and which may be utilized if this area is of concern. There are several more measures which may be utilized to more fully evaluate various aspects of functioning. The astute clinician will seek out these measures in order to determine their appropriateness for various children or adolescents.

Summary and Conclusions

In summary, the Boston Process Approach begins with a sampling of behaviors and then fine tunes the evaluation depending on the initial findings. The strength of the Boston Process Approach is also its weakness; namely, the ability to determine the client's areas of strength and deficit through qualitative data. Qualitative information has improved the prediction of brain damage found on radiological evidence to more than 90 percent (Milberg et al., 1986). Heaton, Grant, Anthony, and Lehman (1981) also found that qualitative data gathered by clinicians using the Reitan battery also showed significant improvement over quantitative scales.

The weakness of the Boston Process Approach lies within the examiner. To avail him- or herself of this approach, the clinician not only must have a wide array of measures in his or her knowledge base, but also sufficient experience in which to apply behavioral observations to brain-behavior relationships. It is also imperative that the clinician have a good database of a "normal" child's performance at various ages.

Although there is a beginning database for the use of the Boston Process Approach with adults (Lezak, 1994; Milberg et al., 1986), data on its efficacy with children are limited. The astute clinician will recognize that best practice will always dictate careful observation of how the child solves the tasks presented to him or her. Although the Boston Approach may be intuitively appealing, further research is needed to determine the benefit of this approach with children.

Delis-Kaplan Executive Function System (D-KEFS)

D. Delis, Kaplan, and Kramer (2001) designed the Delis-Kaplan Executive Function System (D-KEFS) for individuals between the ages of eight to 89 years. The D-KEFS is comprised of nine individually administered tests, and the "battery offers one of the first psychometrically sound, nationally normed set of tests designed exclusively for the assessment of verbal and nonverbal executive functions in children, adolescents and adults" (Shunk, Davis, & Dean, 2006, p. 275). While the D-FEFS contains new tests, other tests have been modified. The battery has an empirical basis and reflects the principles and procedures from the extensive body of literature on executive functions (EF).

The test is organized into four domains: Concept Formation, Flexibility, Fluency and Productivity, and Planning. The D-KEFS contains improved versions of older tests previously described, including the following (Shunk et al., 2006): (1) D-KEFS Trail Making Test measures visual scanning and motor speed; (2) D-KEFS Word Context measures abstract thinking and deductive reasoning; (3) D-KEFS Sorting Tests measures verbal and nonverbal concept formation; (4) D-KEFS Twenty Questions measures object naming and recognition, visual attention and perception; (5) D-KEFS Tower Test measures planning and problem solving, learning, inhibition of impulsivity, and maintenance of instructional sets; (6) D-KEFS Color-Word Interference test is a version of the Stroop test, and measures inhibition and attention; (7) D-KEFS Verbal Fluency Test measures verbal fluency; (8) D-KEFS Design Fluency Test measures verbal fluency in the spatial domain, and(9) D-KEFS Proverb Test measures verbal abstraction.

The technical adequacy of the D-FEFS is an improvement over earlier EF measures particularly with newer, expanded norms and modified measures (Shunk et al., 2006). Initial research with the D-FEFS shows promise with special populations including ADHD (Wodka et al., 2008), and individuals with autism and Asperger's disorders. However, additional reliability and validity research for children is needed (Barron, 2003).

A Transactional Approach to Neuropsychological Assessment

Neuropsychological assessment from a transactional model encompasses evaluation of a child's functioning in many areas of his or her life. Given the basic premise of our model that the child's biobehavioral status acts and is acted on by the environment, it is important that this assessment evaluate home, school, and community functioning as well as neuropsychological performance. The assessment is generally based on the referral question, but must also address additional issues that may be raised during the evaluation process.

This approach avoids many of the shortcomings inherent in other methods of interpretation. The functional approach emphasizes the major behavioral characteristics of each disorder, analyzes how behavioral and cognitive variables correlate with one another, analyzes how these behaviors affect development and change over time, and investigates the neurological substrates of behavioral and cognitive characteristics of a disorder. Further emphasis is placed on determining how non-neurological factors (e.g., family and education) interact with and moderate biological factors (i.e., neurochemical imbalances or structural damage).

In concordance with the functional organizational approach, the transactional neuropsychological approach includes the following: (1) a description of the neuropsychological correlates of the disorder; (2) identification of behavioral characteristics of various childhood disorders; (3) considers moderator variables such as family, school, and community interactions, and (4) determines how the existing neuropsychological constraints interact with the child's coping ability and developmental changes that occur at various ages.

The transactional model further provides a systematic study of the interaction of the child's behavior with his or her neurobiology, not only as a means of assessment but for measuring treatment efficacy (Bergquist & Malec, 2002). This approach is ecologically valid and recognizes the interplay of the child's acts and predispositions to his or her environment and the resulting neuropsychological findings. Thus medical interventions such as psychopharmacology will be measured in juxtaposition with psychosocial interventions and vice versa.

In keeping with these assumptions, a neuropsychological assessment based on the transactional approach includes several domains for examination. The initial approach would be a comprehensive developmental interview with the parents. Such an interview would detail information about the child's birth, temperament, developmental milestones, and social, medical, family, and school history. Medical history needs to include information about the existence of seizure disorder, head injury, illnesses, and any medications the child is currently taking. Not only is it important to gather this information, it is also crucial to gather as much information from parents about their perceptions of the child's strengths and weaknesses, as well as questions they may have about their child's neuropsychological functioning.

The evaluation also needs to contain reports from the child's teacher, which should include behavior rating scales by at least two teachers who know the child well. We find it instructional to use the main teacher plus a teacher of a subject that is less structured than formal academics, such as art or gym. These less structured classes can provide a window into the child's ability to handle situations that may be less predictable. Art, music, and gym classes also frequently provide additional information about the child's social skills. If a special education teacher is providing any services to the child, it is very important that this teacher also complete a behavior rating scale.

The next part of the evaluation involves direct observation of the child. If the child is to be observed in his or her classroom, this should be done before the assessment begins. Although it is always good practice to observe the child in the classroom setting, clinicians in private practice or in clinics generally are unable to do so. If this is the case, then a phone interview (with the parents' permission, of course) with the teacher is strongly suggested to ascertain areas of concern in that setting, consistency of behavior across settings (particularly important with regard to assessing behavioral problems such as ADHD, conduct disorders, and social skills deficits), and interventions that have been attempted and that have failed or succeeded. Observation of the child also takes place during the assessment process. How the child separates from his or her parents, how he or she relates to the examiner and copes with a novel situation, and his or her language skills, affect, and problem-solving strategies during the session are all important areas of observation.

Finally, the transactional assessment process includes information about the presenting problem and selection of measures for that concern as well as any additional areas that emerge during the assessment. Incorporating these data and evolution of an evaluation strategy are integral to the transactional approach to neuropsychological assessment. The domains to be assessed will vary depending on the referral question and on the child's age and developmental level. Screening of areas not believed to be involved is desirable, but not always possible. For example, a child who is suspected of having ADHD but who is performing adequately in school does not need a full achievement battery; if there are recent standardized test scores or group achievement tests, then further evaluation is not required. The examiner can then concentrate on measures of distractibility, attention, impulse control, and activity level. In contrast, a child referred to assess for a possible learning disability may not need a full assessment of attention or emotional functioning, particularly when there is no evidence that these are problem areas. The assessment should be tailored to the child and not the child to an assessment protocol. Therefore, we recommend this approach over a battery approach.

Table 8.8 contains the various domains that are often evaluated in a neuropsychological assessment, along with some suggested measures. It is hoped that these suggestions will assist the clinician in using these measures either to determine the existence of a problem that requires a full neuropsychological evaluation or to gain needed information for the development of an intervention program.

Several of these measures were described earlier in Chapter 4. The interested reader is also referred to the test manuals of standardized tests for more details (e.g., Woodcock-Johnson Psychoeducational Battery-Revised: Cognitive; Clinical Evaluation of Language Fundamentals; Token Test; Differential Ability Test). Many of these measures take little time to administer and can be used as screening devices to confirm a diagnosis or area of concern. Many of the measures listed in Table 8.8 are routinely used by the generally trained clinical or school psychologist. The interpretation of these measures

Table 8.8 Domains for neuropsychological assessment and suggested measures

Gross motor	Fine motor	Visual perceptual
Marching (HINB)	Grooved pegboard	Matching figures, V's, concentric squares, and stars (HINB)
Motor scale (MSCA)	Purdue pegboard	K-ABC subtests
Motor scale (LNNB-CR)	Finger tapping	Rey-Osterreith complex figure
Grip strength test	Tactual performance test	Judgment of line Test
	Bender-gestalt test	Facial recognition
	Trails A	Bender-Gestalt test
	Rhythm (LNNB-CR)	Beery visual-motor integration test
		Hooper visual organization test
Sensory-motor	**Verbal fluency**	**Expressive language**
Tactile, visual, auditory (HRNB, HINB)	Controlled oral word association-FAS	Clinical evaluation of language fundamentals (CELF-R)
Tactile form recognition	Verbal fluency (MSCA)	Vocabulary subtest (SB: FE & WISC-III)
Fingertip writing (HRNB, HINB)		Boston naming test
		Aphasia screening test (HRNB)
Receptive language	**Memory**	**Abstraction reasoning**
CELF-R	Benton visual-retention	Category test (HRNB, HINB)
Token test	Tactual performance test	Wisconsin card sort (WCST)
Peabody picture Vocabulary-Revised	Wide range assessment of Memory and learning (WRAML)	Concept formation test (WJ-R)
Picture vocabulary (WJ-R)	Children's auditory verbal Learning Test (CAVLT)	Trails B (HRNB)
	Rey auditory verbal learning test	Color form test (HINB)
	sentence memory (SB:FE)	Ravens progressive matrices
Learning	**Executive functions**	**Attention**
CAVLT	Wisconsin card sort	Continuous performance test
WRAML	Category test	Cancellation tests (WJ-R; D2)
Rey-auditory verbal learning test	Matching familiar figures (HINB)	Stroop test
Auditory-verbal learning (WJ-R)	Verbal fluency tasks	Seashore rhythm test (HRNB)
		Speech-sounds perception test (HRNB)
		Progressive figures test (HINB)
		Serial 7's

Note: Halstead-Indiana Neuropsychological Battery (HINB); Halstead-Reitan Neuropsychological Battery for Children (HRNB); Kaufman Assessment Battery for Children (K-ABC); Luria Nebraska Neuropsychological Battery-Children Revised (LNNBB-CR); McCarthy Scales of Children's Ability (MSCA); Stanford-Binet Intelligence Scale, Fourth Edition (SB:FE); Woodcock-Johnson Cognitive Battery-Revised (WJ-R); Wechsler Intelligence Scales for Children-Third (WISC-III).

from a functional neuropsychological perspective is what differs between the evaluations. In the transactional approach it is important to assess the varying domains and determine how the results affect the child's ability to relate to his or her environment and to adapt to the resulting environmental reaction. The transactional model interprets the results of these measures and develops an appropriate intervention program.

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