Nonverbal Neuropsychological Assessment

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At the outset, it is important to acknowledge that the term *nonverbal* cannot begin to approximate the multitude of mental operations executed by people during complex behaviors, even when no spoken or written communications are involved. Recent advances in cognitive neuroscience show that human behaviors, when measured with neuro-imaging technologies, correspond to the activation of highly connected neural networks with integrated processes and dynamic interactions across multiple network distributions (van den Heuvel & Sporns, 2013; Sporns & Betzel, 2016). Many of these networks span functionally heterogeneous brain regions and are not modality-specific, activating in response to more than one sensory input or even nonsensory-based ideation. The 1990s-era discovery of *mirror neurons*, multimodal association neurons that increase activity during execution of certain actions or while seeing/hearing corresponding actions performed by others (see e.g., Rizzolatti & Craighero, 2004), has stimulated a dawning awareness now supported by research that a wide range of cognitive activities involve neural simulations or reenactments (Barsalou, 2008). For example, perceiving the handle of a coffee cup activates a grasping simulation (Tucker & Ellis, 1998); judging the weight of an object lifted by someone else activates motor and somatosensory systems (Bosbach et al., 2005); mental rotation of objects is accompanied by motor simulations of turning (Richter et al., 2000); and retrieval of a word stimulates the sensory modality operations performed when the word was encoded (Buckner & Wheeler, 2001). Stating that a test is *nonverbal* says very little about the many verbal areas of the brain that may be activated by its performance. At best, *nonverbal* describes the overt requirements of a test, not the internal mental processes that may be required for performance.

When contrasted with *verbal* assessment, however, the practice of *nonverbal* assessment is practical and easy to understand, accounting for its century-long duration. *Nonverbal assessment* simply describes measurement in which an effort has been made to minimize the use of language (in instructions, materials, and responses) because language functioning *per se* may be irrelevant to the cognitive construct being measured. For example, there is value in identifying relatively spared mental functions in an individual with a known language disorder, so administration of tasks with minimal receptive and expressive language requirements may be helpful and instructive. If tests have lengthy spoken instructions, the examinee with a language disorder may potentially perform at lower levels, even if the measure is intended to tap abilities unrelated to language. Likewise, it is usually ill-advised to administer a measure in the English language to a person proficient in another language (and not in English), since results will invariably underestimate true ability. We would also be exceedingly cautious about administering a measure in spoken English to an individual who is Deaf, unless an ASL translator or appropriate augmentative devices is available. Accordingly, use of nonverbal assessment tools in neuropsychology is indicated for individuals whose English language functioning is likely compromised by their cultural–linguistic, educational, or medical background, including the following special populations: (a) individuals with acquired or developmental speech and language disorder; (b) individuals with limited English proficiency, for whom translated or adapted tests are not available; (c) individuals who are Deaf or hard of hearing; and (d) individuals who, by virtue of their education or cultural experience, cannot be assessed validly with language-based tasks. Nonverbal assessment of language-impaired individuals may provide a truer representation of neurocognitive functioning than can be expected with language-loaded measures, because the role of language as an intervening factor in explaining deficient test performance is minimized. At the same time, it should be considered best practice to first document an examinee's existing language proficiency and competencies with conventional language measures, including the nature and severity of language impairment. Administer an aphasia battery or an English proficiency measure before proceeding to the nonverbal neuropsychological assessment.

Within the scope of clinical practice, neuropsychological assessment involves measurement of higher order dimensions of cognition, principally in the domains of attention and executive functions, memory and new learning ability, language and communication, and visual-spatial cognition. There are few investigations pertaining to the structure of wide-ranging neuropsychological batteries, but in an investigation of Spanish speaking adults administered a neuropsychological battery with "minimal linguistic components" (p. 127), Ardila and Pineda (2000) extracted five relatively independent nonverbal cognitive factors: "attention, executive function, memory, visuoperceptual and visuoconstructive abilities" (p. 135). This chapter addresses nonverbal assessment in these neuropsychological domains, noting that related areas of testing commonly included in neuropsychological batteries (e.g., appraisal of intelligence, personality, and psychopathology) are described elsewhere in this volume and that testing of lower sensory and motor functions already tend to be somewhat independent of language.

A WORKING DEFINITION OF "NONVERBAL" TESTS

The verbal–nonverbal dichotomy cannot be equated with the auditory–visual sensory modality distinction, as there are nonverbal aspects to auditory processing (e.g., processing of environmental and musical sounds) and verbal aspects to visual processing (e.g., identification of meaningful, semantically processed visual details). Efforts to simplify the verbal–nonverbal dichotomy by defining functions in terms of underlying cerebral lateralization (left hemisphere vs. right hemisphere) also represent an oversimplification of reality, since some aspects of language are seated in the right cerebral hemisphere, and some spatial processing is seated in the left cerebral hemisphere. Ennio De Renzi (1982) criticized the association of verbal–nonverbal functioning with lateralized left- and right-hemisphere cortical functions: “There is no need to spend time to demonstrate that labeling the right hemisphere specialization as ‘non verbal’ is heuristically unsatisfactory” (p. 186). Arthur L. Benton (1988/2000) concluded that the verbal–nonverbal dichotomy remains a practical, albeit flawed, way to think about cortical functions. As implied in the brief discussion of neural networks in the introduction to this chapter, behavior always has a multitude of cortical and subcortical underpinnings. Most human behaviors involve a *microgenesis*, or unfolding, of multiple simultaneous complex processes that change over a span of seconds—activating circuits and pathways throughout the entire brain, never just one cerebral hemisphere.

Traditional clinical wisdom holds that the inability to communicate *meaning* is the defining characteristic of disorders of language. Beginning in 1863, Hughlings Jackson (1915) studied language disorders and speculated that at the heart of language disorders was a central deficit in the ability to convey meaning or the formulation of propositions. D. C. Finkelnburg (1870/1979) described language disorders as an inability to manipulate any symbols for communication (*asymbolia*), making it difficult for affected individuals to use even nonverbal gestures or pantomime for communication. Henry Head (1926) built upon the Jacksonian tradition to argue that impaired symbol formation and expression in any context— language and nonlanguage tasks—is the central processing disorder in aphasia. Contemporary theorists continue to emphasize the integral role of *meaning* in language and communication, irrespective of whether communication is spoken, written, or gestural (e.g., Caplan, 1994). This tradition, however, might lead us toward the untenable position that meaningful content is inherently *verbal* (language-based), while content that is not meaningful is *nonverbal*. Fortunately, Barsalou (1999) has theorized that symbolic operations transcend language, for they are part of perceptual processes that record and conceptually interpret experience, as well as driving internal mental simulations.

With these considerations in mind, we offer a working operational definition of *nonverbal tests* that relies upon their objective, observable, and overt performance requirements. The most obvious definition is that nonverbal neuropsychological tests involve no expressive or receptive language requirements from the examinee, but there are so few tests that meet this requirement that it is unduly restrictive. Accordingly, we must arbitrarily define *nonverbal neuropsychological tests* as instruments (a) requiring minimal receptive language of the examinee (usually not more than several sentences to be comprehended as part of the spoken instructions), (b) utilizing stimuli that are not semantic or numerical symbols (e.g., logographs, letters, words, or numbers), (c) requiring minimal expressive language (i.e., only very brief written or spoken verbal responses) on the part of the examinee, and (d) having a theoretical or empirical relationship with the integrity of functioning in the brain.

Our rationale for permitting brief spoken instructions (requiring a little receptive language/comprehension) in a nonverbal test while minimizing expressive language/production is threefold: (a) expressive language deficits, particularly in naming and word-finding ability, are almost universal in language disorders, whereas receptive language deficits are comparatively rarer; (b) receptive language is developmentally acquired before expressive language and tends to be less impaired in developmental disorders than expressive language (e.g., Ballantyne & Sattler, 1991; Clark & Hecht, 1983; Fraser, Bellugi, & Brown, 1963); and (c) the sparing of language comprehension relative to language expression after acquired brain injury parallels the better-known sparing of recognition memory relative to free recall memory (e.g., Channell & Peek, 1989). All things being equal, the ability to comprehend ideas is more resilient to brain injury than the expression of ideas.

Our rationale for excluding printed stimuli that involve semantic or numerical symbols (e.g., letters, words, logographic characters, and numbers) is that most of these graphic forms tend to be semantically represented and therefore heavily dependent upon linguistic processes. For example, most forms of numerical processing are mediated by some form of semantic representation (McCloskey & Macaruso, 1995). The now-ubiquitous rapid automatized naming tests (see Wolf & Denckla, 2005 for the most recent update of the RAN/RAS tests) are based on the finding that (in)efficiency at accessing and mentally retrieving semantically-stored material is associated with a host of language-based learning disabilities, including dyslexia, dysgraphia, and dyscalculia. The exclusion of test stimuli using letters, numbers, or words from our definition of nonverbal tests leads us to abandon some of the best known neuropsychological measures including the Trail Making Test (Army Individual Test Battery, 1944) and the Halstead Category Test (Halstead, 1947) from the Halstead–Reitan Neuropsychological Battery (Reitan & Wolfson, 1985). The evidence from tests like the RAN/RAS convincingly shows that processing of even isolated letters and numbers can be compromised in language-related disorders (e.g., Wolf & Denckla, 2005).

It is theoretically possible to conduct an assessment of language-related functions with nonverbal measures, although there is little reason to do so. For example, language functions such as auditory processing and symbolic communication may be measured with nonverbal tools of sound processing (Seashore, Lewis, & Saetveit, 1960; Spreen & Benton, 1969) and pantomime/gesture recognition (Benton, Sivan, Hamsher, Varney, & Spreen, 1994). Several measures of receptive language and comprehension meet our defining criteria for nonverbal neuropsychological tests (e.g., DiSimoni, 1978; Dunn & Dunn, 2007; Spreen & Benton, 1969), because they involve brief verbal directives to point or manipulate objects with no expressive language.

REPRESENTATIVE NONVERBAL TESTS BY NEUROCOGNITIVE DOMAIN

In this section, we describe applied and theoretical dimensions of assessment within the major neurocognitive domains of attention and executive functions, memory and new learning ability, and visual-spatial cognition. Representative nonverbal measures that tap central neuropsychological functions are described, including information about the constructs they measure, their administration, scoring, and interpretation, and their limitations. These instruments rank among the most widely utilized by practitioners (see Butler, Retzlaff, & Vanderploeg, 1991; Camara, Nathan, & Puente, 2000; Rabin, Barr, & Burton, 2005). In many instances, there may be as many as half a dozen or more adaptations for a given procedure, so only a limited number of representative adaptations can be described in text. For example, there are at least 10 scoring systems for the Rey–Osterrieth Complex Figure (ROCF; Troyer & Wishart, 1997).

In this volume, the psychometric properties of nonverbal tests have been described in detail. In this chapter, however, the psychometric properties of nonverbal neuropsychological measures are not directly addressed, in part because existing psychometric standards have not been traditionally or rigorously applied to neuropsychological tests. It has only been in more recent years that neuropsychological tests have undergone standardizations with nationally representative normative samples (e.g., Delis, Kaplan, & Kramer, 2001; Korkman, Kirk, & Kemp, 2007; White

& Stern, 2001, 2003). Moreover, many neuropsychological tests yield multiple interpretive indices, with variable psychometric qualities, that are evaluated with reference to a large number of independently published norms varying widely in quality. Accordingly, it is difficult to make brief summary statements about psychometric adequacy for almost any neuropsychological test. Thoughtful discussions concerning the psychometric properties of neuropsychological tests are available in Mitrushina, Boone, Razani, and D'Elia (2005) and Strauss, Sherman, and Spreen (2006).

Attention and Executive Functions

Attention and executive functions are interrelated constructs. At the simplest level of analysis, attention involves the allocation of cognitive resources in a given direction, whereas executive functions control the implementation of behaviors with some intended outcome. Theoretical models of attention include elements from the executive functions (Mirsky, 1996), whereas most models of the executive functions include elements (e.g., inhibition) that are central to attention (Eslinger, 1996). In some test batteries, attention and executive functions are separated (e.g., Naglieri, Das, & Goldstein, 2014; White & Stern, 2001, 2003), whereas in others, they are combined (Korkman, Kirk, & Kemp, 2007). Some new conceptualizations of disorders of attention emphasize underlying deficits in executive functions (Barkley, 2015; Tannock & Schachar, 1996). We have always found the approach of Stuss and Benson (1986) to be helpful, that is, that attention and executive functions are hierarchically organized mental processes with executive functions at an upper, superordinate level and attention at a lower level, although the picture is undoubtedly more complex. In this section, we distinguish between attention and executive functions with the recognition that measures of each construct may be readily applied to the other.

In neuropsychology, *attention* is used to describe a wide range of behaviors and processes beginning as soon as environmental events are detected by the senses and involving the subsequent and ongoing allocation of cognitive resources. Attention has the net effect of facilitating cognitive and behavioral performance by filtering and managing incoming stimulation, permitting selection and control of behavioral responses, and maintaining performance over time (Cohen, 1993). Although a number of kinds of attention have been described (e.g., Parasuraman, 1998), most cognitive and neuropsychological models tend to include just a few core types (Cohen, 1993; Koelega, 1996; Stankov, 1988; van Zomeren & Brouwer, 1994):

- *Selective attention*: Ability to preferentially attend to a particular signal while inhibiting attention to competing signals; related to the concept of *focus*.
- *Sustained attention*: Ability over time to maintain a response set or readiness to respond to unpredictable events; related to the concept of *vigilance*.
- *Divided attention*: Ability to simultaneously attend to multiple events or perform multiple tasks; related to the concept of *multitasking*.

In comparison with attention, the *executive functions* refer to a cluster of activating and inhibitory psychological processes that control the formulation, implementation, coordination, and monitoring of sequences of behavioral responses according to short- and long-term goals (Eslinger, 1996). The executive functions tend to be most strongly associated with activity in the prefrontal cortex, as the active force behind voluntary and deliberate behavior (Pribram, 1973; Tranel, Anderson, & Benton, 1995). In his most recent theoretical formulation, Barkley (2012) considers *executive functioning* to be a meta-construct operationally defined as behavioral self-regulation across time for the attainment of one's goals, typically using social and cultural means. In his view, executive functions are self-directed activities that change subsequent behaviors in the service of some objective. There is some variation in the classes of self-regulatory behaviors identified as *executive functions*, but they generally include (a) response inhibition; (b) working memory; (c) organization, strategizing, and planning; (d) cognitive flexibility and shifting; (e) emotional self-regulation and self-motivation; and (f) self-awareness and self-monitoring (e.g., Barkley, 2012).

In the following sections, representative nonverbal measures tapping various aspects of attention and executive functions are reported. Some of the theoretical dimensions cited above have few formal measures and are not included.

Tests of Selective and Sustained Attention

Although there are many measures of selective and sustained attention, the best known tests with nonverbal forms of administration are the continuous performance tests (CPTs). Developed nearly five decades ago (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), the CPTs represent a family of measures intended to assess diverse aspects of attention, along with elements of impulsivity. Ranging from about 10 to 25 minutes in length, the CPTs involve continuous presentation at either regular or variable intervals of low interest stimuli and require the examinee to respond (or *not respond*) to selected stimuli under specific conditions, usually by pressing a button or switch.

Four major continuous performance tests—Conners' continuous performance tests (Conners CPT 3 and Conners CATA), the *Integrated Visual and Auditory Continuous Performance Test* (IVA2), the *Gordon Diagnostic System* (GDS), and the *Test of Variables of Attention* (TOVA and TOVA-A)—currently dominate CPT assessment (Riccio, Reynolds, & Lowe, 2001). Of these, only the *Test of Variables of Attention* (TOVA; Leark, Greenberg, Kindschi, Dupuy, & Hughes, 2007) and its auditory version (TOVA-A) utilize nonlanguage stimuli (i.e., neither letters nor numbers). After a three minute practice test, the TOVA tests for 21.6 minutes (11 minutes for 4 to 5 year olds). Stimuli in the TOVA are two geometric figures, one of which is the target; the auditory version TOVA-A uses two tones, the higher tone being the target. Both measures are nonsequential with a fixed interstimulus interval. The test developers recommend administering the visual and auditory TOVAs about 90 minutes apart or on different days. The instructions for each version of TOVA are provided verbally and include the brief practice test for both the visual and auditory versions to ensure that the examinee understands the testing conditions and instructions. The tests are computer scored and normed for ages 4 years through 80+ years, generating a score and narrative printout (Leark et al., 2007). Results are reported as raw scores, percentages, standard scores, and standard deviations. Scoring indices on the TOVA, like most CPTs, include indices of response variability, errors of omission (traditionally associated with inattention), errors of commission (impulsivity or disinhibition), correct response time (decision time to respond correctly) and postcommission response time (inhibitory responding after making an error), anticipatory responses (number of guesses), and response sensitivity (the ratio of hit rate to false alarm rate).

In the most comprehensive treatment to date, Riccio, Reynolds, and Lowe (2001) have summarized the strengths and weaknesses of the CPTs:

- Most CPT paradigms are sensitive to most types of central nervous system dysfunction;
- CPT performance is adversely affected by metabolic disorders with cognitive sequelae, by schizophrenic disorders, by pervasive developmental disorders, by most externalizing disorders in children, and by some internalizing disorders;
- CPTs tend not to be sensitive to disorders of mood or affect;
- CPTs have high levels of sensitivity and specificity for all forms of Attention Deficit Hyperactivity Disorder (ADHD), but only when ADHD or a typical presentation with no impairment are the only two diagnostic possibilities (and differential diagnosis is not

involved);

- Reliance on CPTs as a primary diagnostic tool in determining the presence of ADHD will result in an unacceptably high number of false-positive errors (i.e., overdiagnosis of ADHD).

Although the CPTs provide norm-referenced information about multiple aspects of attention, the examiner must also consider the testing time investment and examinee motivation relative to the interpretive yield for these unengaging tasks. We sometimes introduce CPT tasks as measures of a person's capacity to remain attentive during very boring classroom or work experiences.

Visual search and cancellation tests constitute a second major class of measures thought to tap selective and sustained attention. These tasks typically involve the presentation of a printed stimulus array with instructions to mark (or *cancel*) specified targets with a pencil. Computerized versions with touchscreen input are rapidly emerging (Dalmaijer, Van der Stigchel, Nijboer, Cornelissen, & Husain, 2014). For example, an examinee may be asked to make a mark on all of the cats appearing in a semirandomly organized array of printed line drawings of animals. A more figural nonverbal stimulus may be found in the Landolt C cancellation tasks, which employ circles with or without a gap for targets and distractors (Parton *et al*., 2006). Performance on cancellation tasks is typically measured according to speed, although errors of commission or omission may be respectively interpreted as indicating difficulty with impulsiveness or inattention, especially if they are concentrated in one hemispatial field. With neglect syndromes, automated computation facilitates identification of visual field inattention severity. For example, the center of cancellation (CoC) is the average horizontal position of cancelled targets, standardized so that a value of -1 corresponds with the leftmost targets and +1 with the rightmost targets (e.g., Rorden & Karnath, 2010). Depending upon specific parameters of the test stimuli, cancellation tasks require selective and sustained visual attention, visual scanning, visual discrimination, access to a full visual field, psychomotor coordination, lower-order (for simple detection) and higher-order (for decision-making) processing speed, and selection and implementation of visual search strategies. Task demands may be varied according to the randomness or structure of the stimulus array, the density and discriminability of the target stimuli relative to distractors, the nature of the decision to be made (e.g., mere detection of a target vs. comparison of multiple targets), the size of the visual field to be searched, and the use of target stimuli from different domains (e.g., letters, digits, pictures, or abstract figures; Cohen, 1993). For example, the tests of directed attention of Mesulam (1985) sometimes show dissociated patterns of performance between detection of the letter “A” (poor performance) and abstract geometric figure detection (adequate performance) in patients with left-hemisphere lesions (Kaplan, 1988), presumably because of the enhanced role of the left cerebral hemisphere in the processing of letter stimuli. A hemiattentional neglect syndrome is suggested when errors of omission are substantially greater for the examinee’s left visual field than right. Profound neglect for the left hemiattentional visual field has been demonstrated in adults with right cerebral hemisphere impairment (Heilman, Watson, & Valenstein, 1993). A generalized slowing of performance may be evident, however, in examinees with a variety of diffuse and focal neurological conditions.

Cancellation tasks differ from the CPTs through use of paper-and-pencil materials (compared to computerized presentation of stimuli), a single-frame simultaneous presentation (compared to a multiframe, sequential presentation), self-paced performance (versus computer-pacing), heightened demands on visual–spatial scanning (versus stimuli presented within a more limited visual field), and heightened demands for visual search strategies (different strategies are required for CPTs). They are similar to the CPTs insofar as they measure sustained and selective attention, usually under conditions of limited interest.

When the stimuli are randomly or semirandomly organized in the array, there are at least two ways of noting the spatial progress of the search over time. The color coding method, recommended by Mesulam (1985), requires that the task be performed with colored pencils, a different color being handed to the patient after the identification of a specified number of targets or after a specified period of time. An alternative method is simply to have the examiner draw a diagram indicating the sequence of targets circled by the patient. Normal adults and adolescents typically conduct a systematic, planful search beginning on the left and proceeding to the right in horizontal or vertical rows even in the random arrays (Kaplan, 1988; Mesulam, 1985). Children younger than 8 or 9 years usually scan and mark shapes in a random, unsystematic sequence. Some assessment procedures ask the examinee to draw their plan of search for an object lost in an open field (e.g., Wilson, Alderman, Burgess, Emslie, & Evans, 1996), permitting easy determination of the efficiency and systematicity of visual searches.

The paper-and-pencil visual search and cancellation tasks offer several important strengths, namely that they are child and adult friendly, simple to administer without computer equipment, and useful for screening visual field deficits. Their chief limitations are short administration duration, thereby limiting their use as measures of sustained attention, and limited prediction to clinical attention-deficit disorders. Normative performance on most of visual search and cancellation tests is dependent on speed, with few errors of omission or commission expected. As a result, children with visual–motor impairments may produce depressed performance, even if there is no attention deficit. Moreover, children, adolescents, and adults with known attention deficits have been shown in general to be prone to fast, inaccurate, impulsive task performance rather than slow, accurate, and reflective performance (Campbell, Endman, & Bernfeld, 1977;

Cohen, Weiss, & Minde, 1972; Hopkins, Perlman, Hechtman, & Weiss, 1979), so tests such as the visual cancellation tasks that can be completed easily without errors may suffer from diminished clinical sensitivity.

Tests of Response Inhibition

Assessment of the executive functions may also include tests that require an examinee to suppress a competing response voluntarily, whether it is a highly automatized response or simply an easier, faster, or shorter pathway to task execution. Tests that involve the suppression of an automatic, easier, or preferred response are considered to tap neural processes of response inhibition. Sergeant, Oosterlaan, and van der Meere (1999) have described 12 assessment paradigms operationalizing response inhibition, a few of which are described below.

A classic and largely nonverbal measure of response inhibition is the Matching Familiar Figures Test (MFFT; Kagan, Rosman, Day, Albert, & Phillips, 1964), in which the examinee is asked to identify which of six choices is perfectly identical to a target picture. The test consists of an elementary set of 12 items and an adolescent/adult set of 12 items. All but one of the six choices (or up to eight choices for the adolescent/adult set) differ in some small, detailed respect from the target, and a careful and deliberate comparison of the choices to the target is required for accurate responding. The MFFT involves spoken directions, only two sentences of which are essential, and requires only a pointing response from the examinee. The examiner records time to the first response, total number of errors for each item, and the order in which errors are made. Responses continue to be coded for each item until the examinee makes a maximum of six errors or gets the item correct. In general, the MFFT is intended to detect children and adolescents who do not take sufficient time to examine the response options carefully, thereby demonstrating an impulsive response style (Kagan, 1965). The MFFT generally yields more errors in individuals with impulsivity-attentional problems compared with normal controls (Douglas, Barr, Amin, O’Neill, & Britton, 1988; Milich, Hartung, Martin, & Haigler, 1994), but performance on it may be depressed for reasons other than defective response inhibition including low intelligence, poor search strategies, and inadequate awareness of the need to inhibit responses until all options have been examined (Schachar & Logan, 1990).

Measures of the ability to inhibit motor responding include the motor impersistence tests, the go/no-go tests and their variants, motor programming, and graphic pattern generation tests (e.g., Cohen, 1993; Denckla, 1985; Goldberg, Podell, Bilder, & Jaeger, 2001). For the most part, these tests are mastered with perfect performance expected at adolescent or preadolescent ages and have very low ceilings. *Motor impersistence* refers to the inability to sustain a directed act or intention and can be demonstrated using a variety of body parts including the limbs, eyes, eyelids, jaw, and tongue (Denckla, 1985; Heilman et al., 1993). In the Benton–Iowa neuropsychological battery, motor impersistence is assessed with eight tests requiring the maintenance of a movement or posture (e.g., keeping eyes closed, protruding tongue; Benton, Sivan, et al., 1994). Norms are provided for ages 5–11, as most adolescents and adults perform these tests without error.

The go/no-go paradigm described by Drewe (1975) and other forms of reciprocal responding (Luria, 1966) involve presentation of a series of stimuli (either verbal or nonverbal) to which the examinee must respond according to specified rules, usually inhibiting the inclination to reciprocate with a response identical to the stimulus or to perseverate to previously given responses. A simple nonverbal version of this task involves instructing the examinee to raise a finger (“go”) when the examiner taps once on the table but to refrain from any movement (“no-go”) when the examiner taps twice (Trommer, Hoeppner, & Zecker, 1991). The children’s game of *Simon Says* may be considered a go/no-go task of behavioral inhibition in which the directed action is to be performed if “Simon says” (“go”), but the action should not be performed if the prefatory phrase “Simon says” is omitted from the directive (“no-go”). The simplest nonverbal form of the reciprocal programming task appears in the NEPSY Knock and Tap subtest, in which the examiner tells the examinee, “When I do this (knock lightly on the table with your knuckles), you do this (tap lightly on the table with your palm). But if I do this (tap lightly), you do this (knock lightly)” (Korkman et al., 1998, p. 171). The task, which is normed for ages 5–12, requires the examinee to respond to a series of knocks and taps with responses that require suppression of the natural inclination to be stimulus bound and echopraxic. This task was not included in the NEPSY-II (Korkman, Kirk, & Kemp, 2007). There are innumerable variations on these clinical paradigms, but relatively few of them are norm referenced.

Measures of motor alternation, sequencing, and programming can be utilized to examine diverse aspects of executive functions, including motor inhibition. Assessment of the formulation, execution, coordination, and maintenance of intentional motor action programs can include varied motor sequences, such as from repetitive sequences touching each of the four fingers to the thumb (a fingers–thumb sequence); sequentially shifting the position of one hand from closed fist to open palm down to open palm held vertically (a fist–palm–side sequence); or alternating simultaneous bilateral hand movements from left palm—right fist to left fist—right palm to left palm—right fist and so on, each program maintained for a specified period of time. The regulation and maintenance of motor tone during execution of these programs with smooth, fluid, and coordinated movements constitutes what Luria (1973) termed a “kinetic melody” that heavily involves activity in the premotor cortex as well as other cortical and subcortical regions. The phenomenon of motor overflow, in which another part of the body moves involuntarily in conjunction with the intentional execution of motor sequences, is considered to be a neurological soft sign that reflects selective motor disinhibition (Denckla, 1985, 1994). Various test batteries including most adaptations of Luria's neuropsychological examination measure motor programming at graded levels of complexity for children and/or adults (e.g., Denckla, 1985; Goldberg et al., 2001; Korkman, Kirk, & Kemp, 2007).

Graphic pattern generation tests typically involve the motor reproduction and continuation of recurring alternating figures, with the expectation that examinees with executive dysfunction may experience difficulty alternating between figures. Examinees are typically asked to reproduce and continue a pattern with either semantic stimuli (e.g., alternating m's and n's: *mnmnmnmn*) or figural stimuli (e.g., alternating peaks and plateaus). Luria (1966) described the reproduction of a series of alternating patterns from a written model, and Goldberg, Podell, Bilder, and Jaeger (2001) included a Graphical Sequences Test in their Executive Control Battery for adults.

Leading measures of behavioral inhibition such as the Stroop task (Stroop, 1935), in which an examinee must selectively attend to and name the color of ink a word is printed in while suppressing the more automatic, prepotent response of reading the word, have reading requirements that make them less-than-optimal for nonverbal assessment. Stroop alternatives without reading requirements include the Day-Night task which requires that children say the opposite of what the stimulus card represents (i.e., saying "day" when shown a black card with a moon and stars, or saying "night" when shown a white card with a sun) (Gerstadt, Hong, & Diamond, 1994). The NEPSY-II Inhibition subtest uses a similar methodology to achieve the Stroop effect (Korkman, Kirk, & Kemp, 2007), but both the Day-Night and Inhibition procedures have expressive language requirements that exclude them from our nonverbal compilation. Similar effects may be achieved, however, through computerized testing with no verbal response required. On the Bivalent Shape Task (Esposito, Baker-Ward, & Mueller, 2013), for example, colored shape stimuli appear in the center of the computer screen with the instruction to *match the shape* to either of two choices--a red circle or a blue square. Instructions for this task, albeit with possibly unnecessary verbiage, state:

> The next computer game is the Shape Game. You are going to match the circles to the circle picture at the bottom and the squares to the square picture at the bottom. We are going to practice first. The first few we do will make a 'ding' if you do it correctly and an 'eh' if you do it incorrectly. That we can make sure you know how to play! The sound will go away after the first few, but that does not mean you are playing it wrong; just keep playing. Let's play the Shape Game! (Esposito et al., 2013, p. 359).

Some stimuli match according to shape and color, while others match ignore the color and respond according to shape. The same approach to responding may be applied to other computerized Stroop-like measures.

Tests of Organization, Strategizing, and Planning

Executive functions also include the capacity to formulate and execute an organized sequence of actions with the objective of accomplishing a goal, or *planning*. For complex tasks, planning tends to be hierarchical, so that a task is broken into smaller subtasks, each with its own intermediate goal that can be accomplished in the service of the higher order objective. Because planning involves the generation of divergent response options, sorting through the options, and selecting one for implementation, it necessarily involves behavioral inhibition, sequential processing, working memory, strategy formation, and ongoing monitoring to appraise progress toward the goal. Lezak (1982) argues that planning is essential for independent, creative, and socially constructive behavior.

Disk-transfer problems, such as the Tower of London (TOL; Shallice, 1982) and Tower of

Hanoi (TOH; Simon, 1975), utilize variations of a look-ahead problem-solving assessment paradigm dating back some seven decades (Ewert & Lambert, 1932). These tasks differ in their cognitive demands, with the TOL solution matching some specified final position and the TOH solution involving placement of all disks on one specified peg. At the same time, they share the qualities of being sensitive to sequential planning abilities, with the quality of performance being measured by the number of moves (or trials) required to arrive at the goal state. Problem-solving strategies used to solve the tower tasks include rote approaches, goal recursion strategies, perceptual strategies, and move-pattern strategies, all dependent upon tradeoffs between perceptual and memory functions (Simon, 1975). The TOL and TOH have both been shown to yield impaired performance in individuals with frontal-lobe lesions (Levin et al., 1996; Pennington & Ozonoff, 1996). Commercial adaptations of these paradigms with contemporary norms are available for the *Tower of Hanoi* (D-KEFS Tower; Delis, Kaplan, & Kramer, 2001) and the *Tower of London* (TOL - Drexel University, Second Edition; Culbertson & Zillmer, 2001). The tower tasks are largely nonverbal, with the examinee response being evident through the sequence of moves. At least one experimental investigation has shown tower tasks to have a substantially lower language load than other executive function measures (Remine, Care, & Brown, 2008).

Planning and strategizing is also thought to be associated with paper and pencil drawing and reproduction of graphic figures, such as the Bender–Gestalt Test and the ROCF. The sequence of placements of the nine Bender–Gestalt figures on a blank sheet of paper has been hypothesized to reveal organization and planning attitudes and skills (Hutt, 1985), and likewise spatial management of elements of other drawings (e.g., person, house, tree, family) within the constraints of an 8.5 X 11 in. (21.59 X 27.9 cm) sheet of paper may also reveal planning deficits. The person with poor planning abilities may leave insufficient space on the page to complete a drawing.

Reproduction by direct copy or memory of complex graphic figures such as the ROCF may also be rated according to the planning based on the order in which elements are drawn, the overall placement of the figure on the page, the placement of elements within the figure, and the overall integrity of the structure of the figure (Stern et al., 1999; Waber & Holmes, 1985).

Tests of Cognitive Flexibility and Shifting

Cognitive flexibility refers to the ability to establish an attentional focus, mental set, or problem-solving approach, and then to appropriately switch to another set according to environmental demands or task requirements. In its pathological form, impaired cognitive flexibility results in a concrete and perseverative style that can be manifested by repeated execution of the same actions or sequence of actions in unsuccessful attempts to accomplish a goal. The individual with adequate cognitive flexibility can shift fluidly and comfortably from one idea to another.

The test most widely used to measure the ability to shift mental set is the Wisconsin Card Sorting Test (WCST; Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993). This test meets our criteria as *nonverbal*, since it has relatively brief instructions and one-word examiner feedback for each response. The WCST requires the examinee to sort up to 128 response cards next to one of four stimulus (or *key*) cards according to a categorical principle, which must be deduced from feedback ("correct" or "incorrect") provided by the examiner after each response. Instructions are fairly nonspecific, requiring examinees to impose organization upon an ambiguous task ("I cannot tell you how to match the cards, but I will tell you each time whether you are right or wrong"; Heaton et al., 1993, p. 5). Sorting principles include matching key card stimuli on several dimensions of the stimuli depicted on each response card. Unknown to the examinee, the examiner will switch the correct sorting principle after the examinee provides 10 consecutive correct responses as a way of eliciting set-shifting abilities. The test continues until six categories have been correctly deduced, all 128 cards have been sorted, or 64 cards have been sorted if not even one category has been deduced.

Scoring on the WCST is challenging even for experienced examiners and should be facilitated with a computer-scoring program. During the test, the examiner indicates on a record form the basis for each card sorted, that is, the identity of the dimensions on which the response card matches the key card. The WCST yields 16 scoring indices, each of which is norm referenced for ages 6 years, 6 months through 89 years, 11 months. Norms are also stratified by education for adults. Percentile ranks, *T* scores, and standard scores are available.

The degree to which the examinee can respond to the new feedback, deduce that the sorting principle has changed, and alter their actions accordingly are the most important performance dimensions tapped by the WCST. Perseverative responses are defined as persistent responses based upon a stimulus characteristic that is incorrect. Once a perseverated-to principle is established, responses that match that principle are scored as *perseverative*, whereas responses that do not match the perseverated-to principle are *nonperseverative*. We will not address additional scoring indices here, except to note that the WCST provides indices describing the ease with which an individual can formulate a conceptual set, maintain that set when responding, and shift away from that set according to changing task requirements. In general, the WCST is considered to provide a valid measure of executive functions that is sensitive (but not specific) to frontal lobe dysfunction (Heaton et al., 1993).

The strength of the WCST is its largely nonthreatening (and low difficulty) format, as well as its minimally verbal instructions and nonverbal stimuli. The examinee is not required to speak during administration (although it is common for the examiner to ask about the examinee's approach after completion of the test). The fractionation of scores including the index of perseverative responding is useful in understanding and identifying the specific processes that may be impaired. At the same time, the WCST has the significant weakness of sometimes putting the examiner in the position of providing negative verbal feedback over a prolonged period of time. Several indices on the WCST (e.g., number of correct sorts) have truncated ranges and low ceilings, rendering them most useful only when significant impairment is present.

In the tradition of the Goldstein-Scheerer Object Sorting Test (Goldstein & Scheerer, 1941), the NEPSY-II Animal Sorting subtest taps concept formation, cognitive flexibility, and self-monitoring (Korkman, Kirk, & Kemp, 2007). The examinee is given eight cards and is asked to sort them into two groups of four cards, each with something in common that the examinee must name; then the examinee must resort the cards into two *different* groups of four, again naming the basis for the sorting. In essence, this task measures how many different ways a person can (re)conceptualize a single situation or a set of stimuli. Unlike the D-KEFS Sorting Test (Delis, Kaplan, & Kramer, 2001), the NEPSY-II Animal Sorting requires no reading, but unfortunately for nonverbal assessment purposes it does require limited verbal expression to convey the concept by which the cards have been sorted.

Another means by which cognitive flexibility may be tapped is through fluency tasks, which require productive output under timed, controlled conditions. Deficits in flexibility may manifest in markedly perseverative output (e.g., Jones-Gotman & Milner, 1977). Verbal fluency tasks, for example, ask an examinee to generate the names of as many different animals as possible, or as many different words starting with a particular letter, within a 60 second time limit. When the initial production strategy runs dry, can the examinee shift to another, and later still another, strategy? On design fluency tasks, which involve asking an examinee to make as many different graphical designs as possible according to specified rules within a given time limit, the same challenges to performance may be found, especially as initial strategies become unproductive. Design fluency tasks may be found in the NEPSY-II (Korkman, Kirk, & Kemp, 2007) and the D-KEFS batteries (Delis, Kaplan, & Kramer, 2001) and involve very little verbalization after initial instructions are provided.

Memory and New Learning Ability

The study of nonverbal memory and learning processes may be traced to some of the earliest studies of amnesia and formal memory assessment. Ribot (1882), who formulated the *law of regression* (stating that memory for recent events is more susceptible to disruption than older memories), described modality-specific amnesias and the loss of memory for symbols. Binet and Simon (1905/1916), in their first intelligence scales at the beginning of the 20th century, included separate procedures to assess retention of visual and verbal material. Their nonverbal memory tests included memory for pictures and figures, both memory assessment procedures that survive to the present day. Early memory assessment resources included Whipple's 1915 compendium that classified tests according to sensory modality involved (visual, auditory, or visual-auditory) and form of visual presentation (simultaneous or successive), as well as multidimensional memory batteries that included nonverbal/performance measures, picture recognition measures, and design reproduction tasks (e.g., Babcock, 1930; Wells & Martin, 1923). By the time that David Wechsler published his first memory scale in 1945, there were there were over 80 available measures of learning, memory, and association, including eight tests or batteries with emphases on memory for figural, pictorial, or visual stimuli (Hildreth, 1939). Since mid-twentieth century, the most widely utilized memory battery has been the Wechsler Memory Scale (e.g., Wechsler, 1945, 2009), which always included at least one nonverbal task as a core subtest. Certainly, nonverbal memory testing is not new.

The clinical distinction between verbal and nonverbal assessment in contemporary clinical memory assessment is usually credited to Milner (1971, 1975), who demonstrated its utility in understanding the sequelae of unilateral temporal-lobe damage. Although the significance of lateralized brain injuries to the cerebral hemispheres is not as differentiated with children as with adults, there has been substantial evidence of modality- and material-specific sequelae in memory functioning (e.g. Bauer, Tobias, & Valenstein, 1993; Warrington, 1984). The link between functioning in the left temporal lobe and verbal memory has proven fairly consistent (e.g., Jones-Gotman, Harnadek, & Kubu, 2000), but evidence for linkage between functioning in the right temporal lobe and visual-spatial nonverbal memory is considerably weaker (e.g., Barr, 2003; Willment & Golby, 2013), perhaps due to unresolved questions about the verbalization of visual-spatial memory performances across a variety of measures. Difficulty extracting nonverbal memory factors from neuropsychological batteries have also led some researchers to wonder if nonverbal memory is a distinct neurocognitive construct, independent from visual-spatial processing in general and conducive to contrasts with verbal memory (e.g., Barr, 2003; Heilbronner, 1992). Still, most omnibus clinical memory batteries and reviews of best practice include nonverbal memory tasks, typically involving stimuli that are visual-figural, visual-pictorial, visual–spatial, perceptual, novel and unfamiliar, difficult to verbalize, and difficult to encode verbally (Moye, 1997).

Tests of Short-Term / Working Memory

The distinction between short-term and long-term memory may be traced back as far as James (1890), who coined the expression “primary memory” to describe awareness of the “specious present” (a span of time extending for several seconds), as distinct from the storehouse of "secondary memory … [which] is the knowledge of a former state of mind after it has already once dropped from consciousness; or rather it is the knowledge of an event, or fact, of which meantime we have not been thinking" (pp. 643–648). James's distinction between primary and secondary memory set the stage for more contemporary distinctions between immediate/short-term memory and long-term memory. Because of the imprecise manner in which short-term and long-term memory are differentiated, practitioners have adopted more functional descriptions of memory tests, that is, those that involve immediate recall (more short-term memory) versus those that involve delayed recall (more long-term memory), and those that involve presentation within normal short-term memory capacity (memory span tasks) and those that are intended to exceed normal short-term memory capacity (supraspan tasks). Working memory is a newer concept, just a few decades old, for which the first generation of clinical measures has just been developed.

At present, short-term memory usually refers to "a limited capacity store" involving uninterrupted sequential recall of material immediately after it is presented (Cowan, 2001; Miller, 1956; Watkins, 1974) and is usually considered to last from a few seconds to a few minutes. Usually tapped by digit span or block span tasks, short-term auditory sequential memory tends normatively to be slightly greater than that of immediate visual sequential memory (Orsini et al., 1987). For simultaneously presented information, however, short-term span of visual apprehension is comparatively unlimited. Short-term memory typically involves passive, temporary, static, and superficial processing of material that is mentally activated and stimulated by sensory input (e.g., seeing and immediately reproducing a simple sequence of visual–motor actions).

There are two main classes of nonverbal short-term span tasks, both analogues to auditory digit span tasks: the Knox Cubes paradigm (Arthur, 1943; Knox, 1914; Stone & Wright, 1980) and the Corsi Block Tapping paradigm (Corsi, 1972; Milner, 1971). The Knox Cubes approach involves tapping a sequence of four 1-inch (2.5 cm.) cubes, placed along a straight line 4 inches (10.1 cm.) apart. The examinee is to reproduce the sequence, span, and location of the taps. Stone and Wright (1980) introduced an updated and Rasch-scaled version of this test that extends from age 2 years through the full range of adulthood. A second approach based upon Corsi's (1972) dissertation increases the spatial demands of block span. Corsi attached nine wooden cubes to a small board, with the cubes numbered on the side facing the examiner for ease of presentation and scoring. Sequences from two to eight cubes are tapped by the examiner at the rate of one block per second, at the completion of which the examinee reproduces the spatial sequence of taps. The Corsi blocks are available near to their original three-dimensional form in the WISC-V Integrated Spatial Span subtest (Wechsler & Kaplan, 2015), with two-dimensional adaptations available in several other measures (e.g., Adams & Sheslow, 2003; Williams, 1991). These measures are all adequately normed, but they likely involve different neural systems of memory than digit span because of their high visual–spatial demands.

Working memory has been defined as the capacity to hold information in mind and perform some active manipulation, operation, or transformation; working memory tends to be more active, flexible, dynamic, and predictive of real-life outcome than short-term memory (e.g., Goldman-Rakic, 1995; Richardson *et al.*, 1996). Working memory has been implicated as an essential aspect of the higher order intellectual functions of language, perception, and logical reasoning (Baddeley, 1986; Baddeley & Hitch, 1974). The emergent role of working memory as a necessary prerequisite for human thinking abilities has been elegantly described by Goldman-Rakic and Friedman (1991): "… the brain's working memory function, i.e., the ability to bring to mind information and hold it 'on line' in the absence of direct stimulation, may be its inherently most flexible mechanism and its evolutionarily most significant achievement. It confers the ability to guide behavior by representations of the outside world rather than by immediate stimulation and thus to base behavior on ideas and thoughts" (p. 73).

Working memory operates "across a range of tasks involving different processing codes and different input modalities" (Baddeley, 1986, p. 35), and distinctive auditory–verbal and visual–spatial subsystems have been hypothesized. The visual-spatial subsystem, which we discuss now because of its association with nonverbal abilities, has been termed the *visuospatial sketchpad* but is now simply described as *visuospatial working memory* (Baddeley, 2000). It probably consists of a system that passively stores visual images along with a companion system that maintains, refreshes, or transforms the images. The mental manipulation or transformation of images associated with working memory is thought to be mediated by prefrontal, executive processes. Visuospatial working memory may be disrupted by irrelevant movement or distracting visual stimuli (e.g., patches of color) and can be dissociated into separate visual and spatial components (Baddeley, 2000). Baddeley (1986, p. 109) emphasized spatial over visual processing by defining the visuospatial working memory as "a system especially well-adapted to the storage of spatial information, much as a pad of paper might be used by someone trying for example to work out a geometric puzzle."

The newest edition of the Wechsler Memory Scale (WMS-IV; Wechsler, 2009) introduced two new visual working memory procedures. In Spatial Addition, the examinee is sequentially shown two grids with blue and red circles (5 seconds of exposure) and is then asked to add or subtract the location of the circles based on a simple set of rules. In Symbol Span, the examinee is briefly shown a series of abstract symbols on a page and is then asked to select the symbols from an array of symbols in the same order they were presented. The diagnostic quality of these measures remains to be determined, but joint factor analyses of the WAIS-IV and the WMS-IV suggested that they collectively form a plausible visual working memory factor, with good model fit to the standardization data in confirmatory factor analyses (Holdnack, Zhou, Larrabee, Millis, & Salthouse, 2011). When scores are combined, the two subtests yield a Visual Working Memory Index in the WMS-IV (Wechsler, 2009).

Another approach to tapping working memory with minimal language may be found in adaptations of the *n*-back procedure, originally developed by Kirchner (1958). In brief, *n*-back procedures involve presentation of a sequence of stimuli, with the examinee indicating when the current stimulus matches the stimulus presented *n* steps previously. The task requires constant updating of items presented and is made considerably more difficult by requiring active comparisons with more steps back. A promising computer-administered nonverbal n-back test may be found in the *Tasks of Executive Control* (TEC: Isquith, Roth, & Gioia, 2010), which permits the levels of working memory (i.e., the number of steps back), as well as comparison of performance under conditions *with* and *without inhibitory control* requirements.

Tests of Long-Term Memory

Long-term memory refers to effective consolidation, storage, and retrieval of newly learned material over time. In clinical practice, it is usually assessed through recall or recognition following a 20- or 30-minute intervening time interval after initial presentation, although the interval may span minutes, hours, days, or longer. It may be distinguished from short-term memory and working memory through its capacity, which exceeds short-term memory span, and its duration, which exceeds the seconds or minutes during which short-term memory processes can remain active. Long-term memory is considered to constitute a relatively permanent memory store from which elements can be retrieved into active mental working space. As conceptualized by Anderson and Bower (1973), “working memory is not structurally separate from long-term memory, but it is the currently active partition of long-term memory" (p. 216).

Measures of recognition memory for meaningful pictorial content constitute a leading way to use nonverbal methods to assess memory in ecologically-relevant ways. These measures typically involve the exposure of one or more pictured objects (e.g., flowers) for several seconds in sequence or simultaneously, followed by a recognition trial in which the examinee must point to the matching object from several choices, including foils that are members of the same semantic class (e.g., different types of flowers) in order to minimize the benefits of verbal mediational strategies. One of the most ecologically relevant tests of this type is the *Wide Range Assessment of Memory and Learning* (WRAML2) Picture Memory subtest (Adams & Sheslow, 2003). In Picture Memory, the child is shown a pictorial scene for 10 seconds and is instructed to look at all parts and to "Take a picture of it in your mind." The initial scene is then removed, and a second, similar scene is presented. The child is asked to mark with an "X" all parts of the picture that have been changed, moved, or added. Errors on the first scene are corrected. Four pictorial scenes are presented altogether. Scoring consists of one point for each correctly identified element in the four scenes. There is no penalty for guessing, although subjects are encouraged to "Just mark the things you are sure of." The admonition to "take a picture in your mind" encourages visual processing. However, this instruction also interrupts spontaneous learning processes and imposes a suggested mnemonic strategy upon the child.

Memory for faces is considered to constitute another ecologically relevant form of nonverbal memory, although its clinical utility as part of memory assessment has yet to be fully and convincingly demonstrated. The first generation of contemporary tests utilizing memory for faces included the Denman Neuropsychology Memory Scale (Denman, 1987) and the Recognition Memory Test—Faces test (Warrington, 1984). The newest face memory procedures involve simultaneous or sequential presentation of multiple faces and subsequent recognition, using either multiple-choice or signal-detection paradigms. For example, the NEPSY Memory for Faces subtest (Korkman *et al*., 2007) involves the serial presentation of faces during which the examinee is directed to verbally identify the gender of each picture (in order to facilitate attention and encoding processes); immediately afterwards, the child is asked to recognize the target pictures from arrays of three faces. Faces have been modified on this task to minimize peripheral details that might facilitate identification, theoretically reducing the benefits from verbal mediation. A 15-25 minute delayed recognition is also utilized.

A more abstract nonverbal memory procedures involves the use of paper-and-pencil constructional tasks with immediate and/or delayed recall of figural material (Larrabee & Crook, 1995). Figural reproduction tasks date at least to Binet and Simon (1905/1916; see also Binet & Henri, 1894), in which two designs were each exposed for 10 seconds followed by immediate reproduction. Among the most widely utilized design reproduction tests are the Benton Visual Retention Test, the Rey-Osterrieth Complex Figure reproduction from memory, and the Wechsler Memory Scale Visual Reproduction subtest (Butler, Retzlaff, & Vanderploeg, 1991; Rey, 1941; Sivan, 1992; Wechsler, 2009). The Benton Visual Retention Test—Fifth Edition (Sivan, 1992) requires that the examinee view each design for 10 seconds and immediately reproduces the designs from memory (administration A). Reproductions are scored by an objective system, including the number of errors and types of errors (omissions, distortions, perseverations, misplacements, and size errors). In order to parse out the effects of visuoconstructional ability without memory demands, the examinee may also reproduce each design while the design remains in view (administration C). The inclusion of a direct copy supplemental procedure to a figure-reproduction memory test permits separation of memory impairment from constructional impairment. This has been a historic criticism of visual memory-testing procedures, i.e., that they are confounded by visuospatial processing ability (Larrabee & Crook, 1995). Measures of figure reproduction from memory as a rule should optimally include separate norms for direct copy reproduction and reproductions from memory. Moye (1997) has reviewed the construct validity and clinical utility for a number of measures of figural memory.

Recognition memory tasks for abstract figural stimuli are another leading methodology used clinically to assess nonverbal learning and memory (Larrabee & Crook, 1995). Stimuli usually involve abstract designs or geometric shapes that are either exposed a single time or recurrently in series. The examinee must then choose the identical stimuli from multiple choices on an immediate and delayed basis. An example of such tasks is the Continuous Visual Memory Test (CVMT; Trahan & Larrabee, 1988), which uses complex ambiguous designs that are not conducive to verbal mediation in a signal detection paradigm. The test has small expressive language requirements, as the examinee must indicate whether they have seen the stimuli before. Recognition paradigms are especially useful for fine motor-impaired clinical populations.

Visual-Spatial Cognition

Spatial cognition has generally been defined to include perception, analyses, and manipulation of stimuli in personal or extrapersonal space. Lohman (1996) emphasizes imagery when he suggests, “Spatial ability may be defined as the ability to generate, retain, retrieve, and transform well-structured visual images” (p. 98). Carroll (1993) includes both perceptual processes and internal operations when he states “Spatial and other visual perceptual abilities have to do with individuals’ abilities in searching the visual field, apprehending the forms, shapes, and positions of objects as visually perceived, forming mental representations of those forms, shapes, and positions, and manipulating such representations ‘mentally’” (p. 304). In their compendium of measures of spatial cognition over 80 years, Eliot and Smith (1983) note that “measures of psychological space typically entail visual problems or ‘tasks’ which require individuals to estimate, predict, or judge the relationships among figures or objects in different contexts” (p. iv).

The neural underpinnings of spatial cognition tend to vary according to the quality of the processing and nature of the information being processed, with the abilities to orient in space, reproduce constructions, and recognize objects through visual or tactile cues most strongly associated with the adequacy of right hemisphere processing of spatial information (De Renzi, 1982). Two separate cortical visual systems have been identified by Mishkin, Ungerleider, and Macko (1983), one a ventral system specialized for object vision (*what* was seen) and the other a dorsal system specialized for spatial vision (*where* it was seen). Consequently, a visual-spatial assessment should tap not only visual content but also visual location.

Performance on specialized tasks such as recognition and learning of unfamiliar faces appears to be mediated by different strategic approaches, with an analytical-sequential approach tending to involve more left-hemisphere activity and a global-synthetic approach involving more activity by the right hemisphere (De Renzi, 1982). The global–local visual-processing distinction proposed by Navon (1977) originally reported evidence supporting the hypothesis that perception proceeds from the global, configural aspect of visual objects to the analysis of more local details. More recent investigations have suggested that individuals with focal left-hemisphere damage are more likely to have difficulty reproducing local, meaningful details, whereas individuals with focal right-hemisphere damage appear to experience particular difficulty reproducing global, configural forms (Delis, Kiefner, & Fridlund, 1988). While we consider many aspects of spatial cognition to have neural underpinnings in the right cerebral cortex, it is clear that analysis of meaningful detail in pictorial material may be seated in the left hemisphere.

Disorders of spatial cognition may take a variety of forms, including various *agnosias* (disorders of recognition), *apraxias* (disorders of intentional movement), and inattention syndromes (De Renzi, 1982). Benton and Tranel (1993) have provided a more behaviorally defined system of classifying disorders including visuoperceptual disorders, visuospatial disorders, and visuoconstructional disorders. Visuoperceptual disorders include visual object agnosias, defective visual analysis and synthesis, impairment of facial recognition (including the *prosopagnosias*, or loss of ability to identify familiar faces), and impairment in color recognition. Visuospatial disorders include defective localization of points in space, defective judgment of direction and distance, defective topographical orientation, unilateral visual neglect, and Balint's syndrome. Visuoconstructional disorders include defective assembling performance and defective graphomotor performance.

Tests of Visuospatial Perception

The integrity of visuospatial processes may be assessed with tests that exclude motor responses or with tests that require perceptual–motor integration. In this section, we describe several measures of nonmotor visuospatial perception. Constructs tapped in this domain of functioning include facial discrimination, figure-ground perception, form constancy, perception of position and direction, spatial relations, visual closure, visuospatial discrimination, and visuospatial working memory, among others. The degree to which these constructs may be differentiated remains an important research question.

Several test batteries assessing diverse aspects of visual perception and processing have been published. For example, the developmental test battery of visual perception originally created by Marianne Frostig in 1964 has been recently revised for children (DTVP-3; Hammill, Pearson, & Voress, 2014) and adolescents/adults (DTVP-A; Reynolds, Pearson, & Voress, 2002). These batteries include measures of figure-ground perception, visual closure, and form constancy that are administered with brief verbal instructions and multiple choice pointing responses. Visual-perceptual test batteries with similar content may be found for children and adolescents (TVPS-3; Martin, 2006) and across the full-age range from childhood to older adulthood (MVPT-4; Colarusso & Hammill, 2015).

Three well-researched visual-perceptual measures from the Benton–Iowa neuropsychological battery readily lend themselves to nonverbal assessment: Facial Recognition, Judgment of Line Orientation (JLO), and Visual Form Discrimination (Benton, Sivan et al., 1994). All three of these tests involve simultaneous presentation of the target stimulus and a multiple choice array of responses (so as to avoid significant memory demands), succinct verbal instructions, and pointing as an acceptable nonverbal response. Screening for adequate visual acuity is recommended prior to administration of most measures of visuospatial cognition.

The Facial Recognition test (Benton, Sivan, et al., 1994) assesses the capacity to identify and discriminate photographs of unfamiliar human faces and is available in two forms, a 27-item short form and a 54-item long form. Administered in a spiral bound booklet, the test involves matching of front-view photographs with identical photographs, with three-quarter-view photographs, and with varied front-view photographs under different lighting conditions. Instructions are brief (e.g., “You see this young woman? Show me where she is on this picture.”), and the test is normed for ages 6 through adult. Age- and education-corrected norms are provided for adults (Benton, Sivan et al., 1994).

The JLO test taps spatial perception and orientation and is available in two 30-item forms. Administered from a spiral bound booklet, it involves matching a pair of stimulus lines (appearing at full length for easier items and partial length for more difficult items) to a multiple-choice array of lines (including full-length representations of the correct responses) drawn from a common origin. Instructions are brief ("See these two lines? Which two lines down here are in exactly the same position and point in the same direction as the two lines up here?"). Examinees can respond by either saying the numbers of the line corresponding to the choices or pointing to the correct responses. Successful performance is suggestive of adequate visuospatial perception of direction, orientation, and position. The JLO is normed for ages 7 through adult (Benton, Sivan et al., 1994).

The Visual Form Discrimination test involves discrimination between complex geometric configurations differing in minor characteristics. Administered from a spiral bound booklet, it consists of 16 items in which the examinee is asked to match a multiple element stimulus design with the identical design from four multiple choice options ("See this design? Find it among these four designs"). The multiple choices are designed in such a way that one features a rotation of a major part of the stimulus design, one features a major distortion of the stimulus design, and one features a rotation in a small figure peripheral to the central design elements. Scores on Visual Form Discrimination are reported to be particularly sensitive to right cerebral hemisphere posterior lesions, although performance may be compromised by lesions elsewhere in the brain and a variety of functional deficits (e.g., sustained attention). The Visual Form Discrimination test is normed for ages 19–74, but the majority of adults have near-perfect performance due to low test ceilings (Benton, Sivan et al., 1994).

Tests of Perceptual–Motor Integration

The assessment of visual-motor integration is most commonly accomplished through paper-and-pencil direct reproduction of figural stimuli, with the leading tests including the Bender–Gestalt Test (Bender, 1938; Brannigan & Decker, 2003), Beery-Buktenica Developmental Test of Visual–Motor Integration (VMI; Beery & Beery, 2010), and the Rey-Osterrieth Complex Figure

(Osterrieth, 1944; Rey, 1941) according to published surveys of neuropsychological test usage (e.g., Butler, Retzlaff, & Vanderploeg, 1991). Measures of visual–motor integration typically require multiple subprocesses: visual-perceptual patterning, visual-perceptual analysis, fine motor abilities, and the transformation and organization of visual-perceptual analyses into coordinated motor programs. Neuropsychological underpinnings of perceptual-motor tasks are relatively nonspecific, involving activity in the motor cortex contralateral to the preferred hand, a variety of right-hemisphere functions (and, to some extent, the left as well as interhemispheric connections), and activity in cerebellar and subcortical nuclei, all thought to be operating in a dynamic, parallel fashion (e.g., Grafton, Mazziotta, Woods, & Phelps, 1992). As the organizational demands in figural reproduction increase (e.g., progressing from reproduction of simple to complex geometric figures), the role of the executive/prefrontal functions becomes more prominent in visual-motor integration.

Perhaps the simplest geometric form copying measure of visual-motor integration is the VMI (Beery & Beery, 2010), now in its sixth edition and normed from ages 2 through 99 years. The VMI consists of 27 geometric figures to be copied with a pencil or a pen, with no erasures permitted. It is supplemented by two tests, one of visual perception and one of motor coordination, intended to parse out the degree to which these narrower abilities contribute to deficient performance. Instructions for the main visual–motor integration test are minimally verbal (“Make one like that. Make yours right here.”), and testing ends after three consecutive no-credit reproductions. Each item may be scored as correct or incorrect, according to one or more criteria. The VMI is most useful for young children or impaired older children, but its score ceiling is low and near-perfect performance is usually evident in early adolescence.

Visual–motor reproduction of complex figures offers an assessment methodology with higher test-score ceilings, as well as the opportunity to more closely examine elements of visuospatial analysis and motor reproduction of basic figures that are spatially integrated. The best known of the complex figures was published by Andre Rey in 1941, although alternative complex figures are available (e.g., Strauss, Sherman, & Spreen, 2006). Assessment with the ROCF usually involves three phases (direct copy, immediate recall, and 20- to 30-minute delayed recall). The direct copy phase administration requires placement of the ROCF stimulus in front of the examinee along with pencil and blank paper, with the essential instructions to “Copy this figure as carefully and as accurately as you can.” There is some variation in these instructions, depending upon the specific normative and scoring system utilized. There is no time limit. Some ROCF administrative methods involve switching the examinee’s writing tools during the production with colored markers to track the sequential development of the drawing, although a graphical flow chart may also be utilized. When the colored markers are utilized, several sentences are typically added to instructions to explain how the examinee will be handed different colored markers during task performance. Once completed, the overall quality of the reproduction may be scored according to Osterrieth’s 1944 criteria using norms and scoring elaborations described by Lezak (1995) or norms collected by Meyers and Meyers (1995). Alternatively, the reproduction may be scored on a number of normed qualitative dimensions (e.g., Stern et al., 1999; Troyer & Wishart, 1997; Waber & Holmes, 1985) such as accuracy, organization, rotation, perseveration, confabulation, and asymmetry.

A third class of perceptual-motor tests involves performance in three dimensions, unlike the paper-and-pencil reproductions we have already described in this section. Manipulation of objects in three-dimensional space may be sensitive to neural impairment that is not evident in paper and pencil constructions and reproductions (e.g., Critchley, 1953; De Renzi, 1982). Block-building tasks to reproduce a model appear in several test batteries of early childhood (e.g., Elliott, 2007; Korkman, Kirk, & Kemp, 2007), but some more complex tasks of three-dimensional block construction involving blocks of varying sizes and shapes are also available (e.g., Benton, Sivan, et al., 1994).

SUMMARY AND FUTURE DIRECTIONS

In this chapter, we have described nonverbal measures of specific abilities within the neuropsychological domains of attention and executive functions, memory and new learning ability, and visual-spatial cognition. The clinical approaches, applications, and limitations of representative tests within each domain have been described. Clinical indications for nonverbal neuropsychological assessment have been described, as well as the history of selected nonverbal assessment procedures.

The vast array of options available to the practitioner wanting to utilize nonverbal tests suggests that the current state of nonverbal neuropsychological assessment is healthy and vibrant. Computer-administered assessment options are proliferating, lending themselves to nonverbal forms of response via the click of a mouse or use of a touchscreen. Nearly every important domain of neuropsychological assessment (with the exception of expressive language) now includes tests with reduced language requirements, suggesting that in the future, it may be possible to conduct a reasonably comprehensive neuropsychological assessment without requiring that the examinee speak. This prospect has particular benefits for examinees who may otherwise not be served because there are no psychologists who speak their native language or because they have lost expressive language functions.

At the same time, it is important to thoroughly research some of the underlying assumptions behind nonverbal assessment, i.e., that it enhances test fairness and reduces construct irrelevant test performance variance with specific populations of examinees. For example, Monica Rosselli and Alfredo Ardila (2003; Ardila & Rosselli, 1989; Rosselli, Ardila, & Rosas, 1990) have persuasively made the case that impoverished and illiterate samples demonstrate depressed nonverbal task performances in areas of attention and executive functions, memory, and visual-spatial constructional ability. We are still surprised to see psychological tests described as “virtually culture-free” (Beery & Beery, 2010, p. 1), long after such claims should have been discredited.

It may also be argued that enhancing the nonverbal administration of most neuropsychological tests may improve test validity and reduce the construct irrelevant variance introduced by the high language loads of most neuropsychological measures. Excessive instructional verbiage may tax examinee language comprehension and memory, thus unintentionally tapping extraneous neuropsychological constructs. We recommend that test developers routinely abbreviate instructional sets and provide alternative gestural instructions in test manuals. Assessment paradigms need ultimately to target their intended neuropsychological constructs in the truest and most focused manner possible, and sometimes language may constitute an impediment to assessment. Nonverbal testing provides a good solution when, to borrow a phrase, words get in the way.

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