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# Neurocognitive Applications of the WJ-IV

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**Neurocognitive Applications of the WJ-IV**

Richard W. Woodcock originally developed the Woodcock-Johnson Revised (WJ-R: Woodcock & Johnson, 1989) with neuropsychological assessment in mind. Woodcock (1997) noted: "Although the WJ-R does not cover all aspects required for a comprehensive neuropsychological evaluation, it does provide more coverage for the assessment and description of deficits and preserved neurocognitive functions than any other single source" (p. 1). The Dean-Woodcock Neuropsychological Model was proposed in 1999, which provided an integration of sensory-motor functioning with the empirically-validated cognitive abilities and academic achievement measures from the WJ (Dean & Woodcock, 1999). In 2003, the Dean-Woodcock Neuropsychological Battery was published (Dean & Woodcock, 2003), which was based on the Dean-Woodcock Neuropsychological Model and provided clinicians and researchers a co-normed assessment tool for neuropsychological assessment.

The current version of the Woodcock-Johnson, the Woodcock-Johnson – Fourth Edition (Schrank, McGrew, & Mather, 2014a), is a broad-based battery of cognitive, oral language, and achievement tests based on the Cattell-Horn-Carroll (CHC) theory of cognitive abilities (Schneider & McGrew, 2012). The WJ-IV consists of three co-normed test batteries: the Woodcock-Johnson IV Tests of Cognitive Abilities (WJ-IV COG: Schrank, McGrew, & Mather, 2014b), the Woodcock-Johnson Tests IV Tests of Oral Language (WJ-IV OL: Schrank, Mather, & McGrew, 2014b), and the Woodcock-Johnson IV Tests of Achievement (WJ-IV ACH: Schrank, Mather, & McGrew, 2014a).

Schneider and McGrew (2012) noted areas of growth regarding CHC theory and its application to cognitive assessment and labeled this growth as "beyond CHC theory" (p. 109). The WJ-IV has incorporated additional neuropsychological constructs into the overall battery such as enhanced auditory processing, working memory, and fluency measures. Schneider and McGrew (2012) stated:

> The most active CHC ‘spillover’ has been in the area of neuropsychological assessment…..It is our opinion that CHC-based neuropsychological assessment holds great potential. Much clinical lore within the field of neuropsychological assessment is tied to specific tests from specific batteries. CHC theory has the potential to help neuropsychologists generalize their interpretations beyond specific test batteries and give them greater theoretical unity (p. 109).

The purpose of this chapter is to review the application of the WJ-IV batteries from a neuropsychological perspective. The first section of the chapter presents a re-classification of the WJ-IV tests into a neuropsychological conceptual framework. The second section of the chapter provides a review of what basic neurocognitive constructs are addressed and assessed by the WJ-IV tests of cognitive, oral language, and achievement. The final section of the chapter provides an example of how the learning and memory tests may be interpreted from a neuropsychological perspective.

**WJ-IV Tests Classified According to a Neuropsychological Model**

Flanagan, Alfonso, Ortiz, and Dynda (2010) were the first to present a classification of the subtests from the major tests of cognitive abilities and pediatric neuropsychological measures using either a Lurian theoretical model, the school neuropsychological conceptual model (Miller, 2007), or the CHC nomenclature. Flanagan and colleagues referred to this as an integrated framework. In 2013, Miller updated his school neuropsychological conceptual model by providing additional integration between neuropsychological constructs and CHC theory. Miller’s revised model, now referred to as the Integrated School Neuropsychological / Cattell-Horn-Carroll (Integrated SNP/CHC) Model (Miller, 2013) is based on current psychometric theory and research (Flanagan, Alfonso, & Ortiz, 2012; Horn & Blankson, 2012; Keith & Reynolds, 2012; Schneider & McGrew, 2012; Schrank & Wendling, 2012) and ongoing discussions with the CHC theorists and cross-battery researchers.

The Integrated SNP/CHC Model encompasses four major classifications: a) basic sensorimotor functions, b) facilitators and inhibitors for cognitive processes and acquired knowledge skills, c) basic cognitive processes, and d) acquired knowledge. In addition to these four major classifications, the test results must be interpreted within the context of the child's social-emotional, environmental, and cultural backgrounds. Within each of these major classifications, the neuropsychological constructs are further classified into broad areas, and even further classified into second order classifications and then third order classifications, as appropriate. As an example, tests within the broad classification of sensorimotor functions can be further classified into the second order classifications of: lateral preference, sensory functions, fine motor functions, visual-motor integration skills, visual scanning, gross motor functions, and qualitative behaviors. Some of these second order classifications can be further subdivided into third order classification such as the sensory functions domain, which can be subdivided into auditory and visual acuity, tactile sensation and perception, kinesthetic sensation and perception, and olfactory sensation and perception. For the sake of simplifying the Integrated SNP/CHC Model for this chapter, only the broad and second order classifications of the model are presented in Table 1 along with the classification of the WJ-IV tests.

In this chapter, the tests from the WJ-IV Tests of Cognitive Abilities, Oral Language, and Achievement are classified according to the Integrated SNP/CHC Model (see Table 1). See Miller (2013) for how other common neuropsychological tests are classified into the Integrated SNP/CHC Model. The purposes of the Integrated SNP/CHC Model are to: 1) facilitate clinical interpretation by providing an organizational framework for the assessment data; 2) strengthen the linkage between assessment and evidence-based interventions; and 3) provide a common frame of reference for evaluating the effects of neurodevelopmental disorders on neurocognitive processes (Miller, 2013). The complete SNP Model includes the integration of social-emotional functioning with the major neuropsychological assessment components (see Miller, 2013; Miller & Maricle, 2012, 2014 for comprehensive reviews).

**Coverage of Basic Neurocognitive Constructs by the WJ-IV Tests of Cognitive Abilities, Oral Language, and Achievement**

Table 2 also provides a list of the WJ-IV tests classified according to the Integrated SNP/CHC Model, but adds additional information to aid in clinical interpretation. Each test includes a brief description of the task(s), the CHC narrow ability(ies) measured by the task, the input, processing, and output demands of the task, as well as, the primary neuroanatomical regions of the brain associated with the task. The input, processing, and output requirements of each WJ-IV measure were derived by conducting demand analyses (Fiorello, Hale, & Wycoff, 2012; Hale & Fiorello, 2004). Tests can be grouped in the same conceptual classification but can yield very different results due to the subtle changes in the input, processing, or output demands of the task. In a later section of this chapter, the differences in the demand characteristics of learning and memory tests will be discussed.

**Basic Sensorimotor Functions**. The WJ-IV does not provide direct measures of basic sensorimotor functions. The sensory-motor portion of the *Dean-Woodcock Neuropsychological Battery* (DW: Dean & Woodcock, 2003) was developed to be a companion to the Woodcock-Johnson III Normative Update Tests of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001, 2007a) and the Tests of Achievement (Woodcock, McGrew, & Mather, 2001, 2007b). The

DW provides a comprehensive assessment of sensory motor functioning; however, the test has not been re-normed with the WJ-IV. If sensorimotor deficits are suspected within a neuropsychological evaluation, it is recommended that additional tests be administered such as the sensorimotor subtests from the NEPSY-II (Korkman, Kirk, & Kemp, 2007).

The WJ-IV COG has two tests, Pair Cancellation and Number-Pattern Matching, which indirectly measure, or require, good visual scanning skills to complete the tasks. Poor visual scanning skills can negatively impact the ability to read words on a line, or write text on a straight line, or efficiently search for embedded visual information with an array of data (Miller, 2013). When using the WJ-IV, sensory-motor functions must be inferred from qualitative observational data and known historical medical information. The WJ-IV does not require fine-motor manipulative tasks, unlike other tests of cognitive abilities, such as Wechsler Intelligence Scale for Children – Fifth Edition (WISC-V: Wechsler, 2014), which require tasks such as Block Design.

**Cognitive processes**. In the Integrated SNP/CHC Model, Miller (2013) identified four principal cognitive processes: visuospatial, auditory/phonological, learning and memory, and executive functions. These basic cognitive processes are influenced by basic sensory functions, are modulated by the facilitators and inhibitors, and influence acquired knowledge.

**Visuospatial**. The WJ-IV authors include the Visualization and Picture Recognition tests as measures of *Gv*. The Visualization test consists of two subtests: Block Rotation and Spatial Relations, which require recognizing spatial configurations with and without mental rotations. The right occipital-temporal region, called the ventral stream, is the area of the brain responsible for recognition of objects (Ungerleider & Mishkin, 1982). The bilateral frontal-parietal network in the brain is activated during the performance of mental rotation tasks similar to the ones used on the WJ-IV (Millivojevic, Hamm, & Corballis, 2009). It is also important to note that more complex visual rotational tasks (e.g., dual axis rotations) place additional demands on executive processes thus simultaneously activating cortical areas within the dorsolateral prefrontal cortex (Just et al., 2001).

In the Integrated SNP/CHC Model, Miller (2013) classifies the Picture Recognition test as an example of a visual immediate memory task, rather than a *Gv* test. The Picture Recognition test does require visuospatial *Gv* skills at a rudimentary level, but the key processing demands of the task involve visual immediate memory. From a neurocognitive perspective, the *Gv* abilities are not fully assessed by the WJ-IV and should be supplemented with other cross-battery measures as needed (see Miller, 2013 for a comprehensive list).

**Auditory/ Phonological**. The test authors have significantly enhanced the measurement of auditory processing (*Ga*) in the revision from the WJ III NU to the WJ-IV. *Ga* abilities have become more widely recognized as playing a major scaffolding role in language development and in general cognitive abilities (Conway, Pisoni, & Kronenberger, 2009). From a neuropsychological perspective, *Ga* can be divided into separate omnibus processing streams, a spatial stream that originates in the caudal part of the superior temporal gyrus and projects to the parietal cortex, and a pattern or object stream originating in the more anterior portions of the lateral belt (Rauschecker & Tian, 2000).

*Ga* is measured by the new WJ-IV COG Nonword Repetition and Phonological Processing tests, and by the WJ-IV OL Sound Awareness, Segmentation, and Sound Blending tests. The narrow ability of phonetic coding (PC) is the principal cognitive skill required for all of these tests, which requires activation of the bilateral posterior-superior temporal regions of the brain (Hickok & Poeppel, 2000). Schneider and McGrew (2012) added an additional narrow ability to *Ga* called memory for sound patterns (UM), which is a cognitive processing requirement for the WJ-IV COG Nonword Repetition test. UM seems to be related to processing within the ventral aspect of the inferior parietal cortex (Ravizza, Delgado, Chein, Becker, & Fiez, 2004).

**Learning and Memory**. A thorough assessment of learning and memory processes is very complex. Some tests focus on only one aspect of learning and memory such as immediate memory or working memory. Miller (2013) classified the broad area of learning and memory into six second order classifications: rate of learning, verbal immediate memory, visual immediate memory, delayed verbal memory, delayed visual memory, and verbal-visual associative learning and recall. The WJ-IV provides assessment of learning and memory in the areas of verbal and visual immediate memory, and verbal-visual associative memory, but does not provide any tests designed to measure rate of learning or delayed recall or recognition. If a clinician is concerned about an examinee's learning and memory, additional cross-battery assessment of these constructs would be warranted and can be obtained by administering one of the stand-alone learning and memory tests such as the Wide Range Assessment of Memory and Learning – Second Edition (WRAML-2: Sheslow & Adams, 2003), the Test of Memory and Learning – Second Edition (TOMAL-2: Reynolds & Voress, 2007), or the Wechsler Memory Scale – Fourth Edition (WMS-IV: Wechsler, 2009).

The WJ-IV COG Story Recall test measures the narrow ability of Meaningful Memory (MM). This MM task requires the comprehension of narratives, which involves multiple brain regions such as those areas along the middle and superior temporal gyri and inferior cortex for general language processing (Ferstl & von Cramon, 2001). In addition, specific regions such as the anterior temporal lobes (Ferstl, Neumann, Bogler, & von Cramon, 2007) and the dorsomedial prefrontal cortex (Hasson, Nusbaum, & Small, 2007) are also involved due to the cognitive demands necessary for comprehension of text.

The narrow ability of Visual Memory (*Gv*-MV) is measured by the WJ-IV COG Picture Recognition test. The left ventrolateral prefrontal cortex seems to be involved in the processing of immediate memory for pictures (Sanefuji et al., 2011). Finally, the narrow ability of Memory Span (MS) is measured by the WJ-IV COG Memory for Words and the WJ-IV OL Sentence Repetition tests. The left ventrolateral frontal cortex is preferentially active during the encoding of words of sentences, but these regions do not retrieve the information. It is the right dorsolateral frontal cortex and the bilateral posterior parietal cortex that are active in memory retrieval (Tulving, Kapur, Craik, Moscovitch, & Houle, 1994).

**Executive Functions**. The WJ-IV COG has four measures of executive functions, which are viewed as synonymous with the CHC broad ability of fluid reasoning (*Gf*). Number Matrices and Number Series were taken from the WJ III Diagnostic Supplement (Woodcock, McGrew, Mather, & Schrank, 2003, 2007) and added to the WJ-IV COG. The WJ-IV COG Concept Formation test is a measure of inductive reasoning and involves the prefrontal-striatal-thalamus loop (Liang et al., 2010). The WJ-IV COG Analysis-Synthesis test measures the narrow ability of General Sequential Reasoning (RG), which involves the left-frontal parietal and basal ganglia regions of the brain (Prado, Chadha, & Booth, 2011). Interestingly, a series of recent empirical studies (e.g., Au et al., 2014; Chuderski, 2013, Colom et al., 2015) suggests that performance on executive functioning tasks such as *Gf* is governed by number of intermediary cognitive processes such as *Gwm* and *Gs*. Thus, clinician’s should be mindful of the potential influence of these and other related facilitating cognitive factors when appraising an individual’s performance on higher order measures of executive functioning on the WJ-IV.

WJ-IV COG Number Series and WJ-IV ACH Number Matrices tests measure the narrow ability of Quantitative (or numerical) Reasoning (RQ). Wilson and Dehaene (2007) have suggested that tasks that involve RQ involve manipulation of the internal number line, which activates the horizontal intraparietal sulcus within the parietal cortex (number sense). The reasoning aspects of these two tasks also involve the left-frontal parietal and left basal ganglia regions of the brain.

**Facilitators/Inhibitors.** The Integrated SNP/CHC Model (Miller, 2013) includes a broad classification called facilitators/inhibitors, which comprises three broad categories: 1) allocating and maintaining attention, 2) working memory, and 3) speed, fluency, and efficiency of processing. These three processes act to either facilitate or inhibit higher order cognitive processes such as executive functions and learning and memory.

**Allocating and Maintaining Attention**. Attentional skills are a prerequisite skill for the majority of the WJ-IV tasks; however, the WJ-IV COG Pair Cancellation test is the only test that specifically measures selective/focused and sustained attention. The right prefrontal and the anterior cingulate of the brain are related to allocating and maintaining attentional control (Posner & Raichle, 1994). Clinicians must exercise caution when interpreting higher order cognitive skills, such as learning and memory or executive functions, when an underlying attentional processing deficit is present. This is due to the fact selective/focused attention mediates all cognitive processing tasks (Cowan, 1988). If poor performance on these tasks is observed, additional assessment may be needed so that clinicians can determine the underlying neurocognitive mechanism responsible for the observed performance. If attentional processing deficits are suspected as part of the referral question(s), the clinician should add additional cross-battery tests from the NEPSY-II (Korkman Kirk, & Kemp, 2007), such as the Auditory Attention and Response Set test or select tests from the Test of Everyday Attention for Children (TEA-Ch: Manly, Robertson, Anderson, & Nimmo-Smith, 1999).

**Working Memory**. A welcome change to CHC nomenclature from the WJ III to the WJ-IV was the relabeling of the broad CHC ability, short-term memory (*Gsm*) to working memory (*Gwm*) (Schneider & McGrew, 2012). The revised working memory label is more consistent with the neuropsychology literature. In contrast to other contemporary cognitive batteries (e.g., WISC-V), the WJ-IV provides users with an array of *Gwm* assessment measures beyond traditional digit span (forward and backward) tasks. An additional test, Verbal Attention, was added to the WJ-IV COG to strengthen the assessment of working memory. In addition to the Verbal Attention test, the WJ-IV COG has the Object-Number Sequencing test (formerly called Auditory Working Memory) and the Numbers Reversed test. Each of these three tests measure verbal working memory, which involves a left-hemispheric network consisting of the lateral frontal (premotor region) and the inferior parietal lobes (supramarginal gyrus) (Ravizza, Delgado, Chein, Becker, & Fiez, 2004). For a thorough assessment of working memory, it is recommended that the clinician also assess visual working memory using tests from other cognitive batteries, [e.g., Symbolic Working Memory test from the WRAML-2 (Sheslow & Adams, 2003)].

**Speed, Fluency, and Efficiency of Processing**. The neurocognitive constructs of processing speed, fluency, and efficiency have been poorly defined up until the recent past (Miller, 2013). Based on a synthesis of many exploratory and confirmatory factor analytic studies, McGrew (2005) and McGrew and Evans (2004), and Schneider and McGrew (2012) concluded that processing speed (*Gs*) might be best considered as a set of hierarchically organized speed taxonomy. Miller (2013) expanded on the idea of a multifaceted model of processing speed and proposed a broad classification of facilitators/inhibitors for speed, fluency, and efficiency of processing. Miller took this broad classification and sub-classified it into four second-order classifications: 1) performance fluency, 2) retrieval fluency, 3) acquired knowledge fluency, and 4) fluency in relation to accuracy.

Performance fluency "is defined as the ability to quickly perform simple, repetitive tasks", which do not require assessing prior learning (Miller, 2013, p. 399). The WJ-IV COG has three tests that can be classified as performance fluency measures: Letter-Pattern Matching, Number-Pattern Matching, and Rapid Picture Naming. Letter-Pattern Matching is a new test to the WJ-IV and measures the narrow CHC ability of perceptual speed (P). Number-Pattern Matching (formerly called Visual Matching on the WJ III NU) is also a measure of the narrow ability of P. Efficient perceptual speed seems to be related to the white matter organization in the parietal and temporal lobes and to connections between these areas and the lateral prefrontal lobes (Ferrer, Whitaker, Steele, Green, Wendelken, & Bunge, 2013; Turken, Whitfield-Gabrielli, Bammer, Baldo, Dronkers, & Gabrieli, 2008). Rapid Picture Naming measures the narrow abilities of Naming Facility (NA) and Speed of Lexical Access (LA), which are processes related to the left temporal lobe region of the brain for lexical access (Shaywitz et al., 1995).

Retrieval fluency "is defined as how quickly information can be retrieved from long-term memory" (Miller, 2103, p. 399). The WJ-IV OL Retrieval Fluency test is designed to measure the narrow abilities of Ideational Fluency (FI) and Speed of Lexical Access (LA), which is again related to left temporal lobe functions (Shaywitz et al., 1995). Acquired Knowledge Fluency "relates to the automaticity of academic achievement including: reading fluency, writing fluency, and mathematics fluency" (Miller, p. 399). The WJ-IV ACH test battery has five measures of acquired knowledge fluency: Oral Reading, Word Reading Fluency, Sentence Reading Fluency, Sentence Writing Fluency, and Math Facts Fluency.

The WJ-IV ACH Oral Reading test measures the narrow abilities of Reading Decoding (RD) and Verbal (printed) Language (V). This test also has a strong fluency component. Reading fluency is further assessed on the WJ-IV ACH using the Sentence Reading Fluency and the Word Reading Fluency Test. These reading fluency measures tap a variety of cognitive processes including reading decoding, reading comprehension, and reading speed. The reading fluency aspect is related to the left occipital/fusiform gyrus regions of the brain (Benjamin & Gabb, 2012), and the reading comprehension component of these tasks relates to the right inferior longitudinal fasciculus and the superior longitudinal fasiculus (Horowitz-Kraus, Grainger, DiFrancesco, Vannest, & Holland, 2014).

Writing fluency is measured by the WJ-IV ACH Sentence Writing Fluency test, which is related to left basal ganglia functions within the brain (Swett, Contreras-Vidal, Birn, & Braun, 2010). The WJ-IV ACH Math Fluency test measures the narrow abilities of Number Facility (N) and Mathematic Achievement (A3). The horizontal segment of the intraparietal sulcus is activated whenever a mathematical operation needs to access a quantitative representation of numbers, such as what is required in math fluency tasks (Dehaene, Piazza, Pinel, & Cohen, 2005).

**Acquired Knowledge.** Acquired knowledge is the broad term used in the Integrated SNP/CHC Model (Miller, 2013), which encompasses the acculturation knowledge, language abilities, and reading, writing, and mathematics achievement. This next section of the chapter will review the WJ-IV tests associated with each of these five types of acquired knowledge.

**Acculturation Knowledge**. Horn and Blankson (2012) first used the term acculturation knowledge to describe *Gc*, and is synonymous with CHC label comprehension-knowledge. Within the acculturation knowledge broad classification, Miller (2103) defined a second order classification called semantic memory, which includes verbal comprehension and general information knowledge. The WJ-IV COG Oral Vocabulary test measures the narrow abilities of Lexical Knowledge (VL) and Language Development (LD). This test requires the examinee to retrieve synonyms and antonyms for words, which involves lexical access within the middle temporal gyrus and the inferior temporal gyrus (Binder et al., 2000). The WJ-IV COG General Information test requires semantic memory activation and retrieval, while the WJ-IV ACH tests of Science, Social Studies, and Humanities require retrieval of specific content knowledge. Retrieval of factual knowledge requires the inferior frontal gyrus and the anterior cingulate (Borst & Anderson, 2013).

**Language Abilities**. Miller (2013) identified two second-order classifications of Language Abilities: 1) oral expression, and 2) receptive language or listening comprehension. The WJ-IV OL Picture Vocabulary test measures the CHC narrow abilities of Lexical Knowledge (VL) and Language Development (LD). The ability to recognize and name pictured objects requires retrieval of vocabulary knowledge, which is related to left prefrontal cortex functions with contributions from the temporal, anterior cingulate, and cerebellum (Binder, Frost, Hammeke, Cox, Rao, & Prieto, 1997). The WJ-IV OL Oral Comprehension test measures the CHC narrow ability of Listening Skills (LS), which is related to the left temporoparietal region (Wernicke's Area) for receptive language processing and the left prefrontal cortex for retrieval (Berl et al., 2010). The WJ-IV OL Understanding Directions test measures two CHC narrow abilities: Listening Skills (LS) and Working Memory Capacity (WM). Based on the neurocognitive demands of this test, it could be classified as either a component of Acquired Knowledge: Language Abilities or as a Facilitator/Inhibitor: Working Memory task. The listening skills part of the task requires the left temporoparietal region (Wernicke's Area) and the working memory part of the task requires the left supramarginal gyrus in the inferior parietal lobes and the lateral frontal (premotor) region of the brain (Ravizza, Delgado, Chein, Becker, & Fiez, 2004).

**Reading Achievement**. Tests from each of the WJ-IV batteries (COG, OL, & ACH) contribute to a broad assessment of reading achievement and the cognitive skills predictive of reading achievement. Reading disorders in children are widely believed to reflect an underlying weakness in phonological awareness (PA), which is the ability to recognize and manipulate the sound structure of words (Wagner & Torgesen, 1987). The WJ-IV ACH tests of Letter-Word Identification and Word Attack were designed to measure aspects of PA. Verbal-visual associative learning is an important prerequisite skill for reading fluency (Newman & Joanisse, 2011), which in turn influences reading comprehension. The WJ-IV COG Visual-Auditory Learning test was designed to measure verbal-visual associative learning.

Some children with reading disorders also have deficits in rapid automatized naming (RAN), either in isolation or in combination with PA deficits (Katzir, Kim, Wolf, Morris, & Lovett, 2008). RAN is the speed that one can name out loud a series of visually presented familiar stimuli such as colors, letter, numbers, or words. The WJ-IV OL Rapid Picture Naming test was designed to be a RAN measure. RAN measures reflect the automaticity of processes, which are important for reading (Norton & Wolf, 2012). Wolf and Bowers (1999) proposed the double-deficit hypothesis where RAN and PA may either independently, or combined, be the cause of reading disorders in children. Subsequently, a host of empirical evidence has since confirmed the role of these foundational neurocognitive constructs with respect to development of reading difficulties across the lifespan (Cronin, 2013). Norton et al. (2014) used functional magnetic resonance imaging (fMRI) to explore the functional neuroanatomical basis of the double-deficit hypothesis model of developmental dyslexia. PA tasks activated the left inferior frontal and inferior parietal regions of the brain; whereas, the RAN tasks activated the right cerebellar VI region of the brain.

The WJ-IV ACH Passage Comprehension, Reading Recall, and Reading Vocabulary are tests designed to measure reading comprehension. Reading comprehension is typically thought to rely on the automatic recognition of language, which in turn is generally thought to reflect left hemispheric processing (Horowitz-Kraus et al., 2014). Horowitz-Kraus and colleagues (2014) found that the known language tracts in the brain, the right inferior longitudinal fasciculus and the superior longitudinal fasiculus tracts were positively correlated with scores from the WJ III Passage Comprehension test (Woodcock et al., 2001, 2007a). They also reported that imaging data collected during reading comprehension tasks showed greater activation in the right hemisphere, than previously expected.

**Written Language Achievement**. The WJ-IV ACH includes four tests of written language: Editing, Writing Samples, Spelling, and Spelling of Sounds. Editing skills are related to the recall and application of the rules for proper punctuation and capitalization and the application of those rules. Precise location of this function within the brain is not known at this time, but the retrieval of the rules and the application of the rules is likely related to left prefrontal activity. Writing is a complex process that includes phonological and orthographical functioning, the lexical level of functioning, syntax, and pragmatics. The frontal lobes must be able to retrieve specific linguistic information upon demand, hold that information in working memory, and assemble that information using a logical motoric output (Feifer, 2013). The frontal areas of the language-dominant hemisphere and the cerebellum are the broad-based regions of the brain activated during writing tasks. In fMRI studies, spelling tasks activated the left fusiform gyrus, left supramarginal gyrus, and the inferior frontal cortex (Norton, Kovelman, & Petitto, 2007).

**Mathematics Achievement**. The WJ-IV ACH includes two tests, Calculations and Applied Problems, designed to measure several narrow abilities related to mathematics achievement. Both tests measure the CHC narrow ability of Mathematical Achievement (A3), while the Applied Problems test also measures Quantitative Reasoning (RQ). The brain structures associated with mathematical computations and mathematical reasoning involve the frontal, left, and right hemispheres (Maricle, Psimas-Fraser, Muenke, & Miller, 2010). Neuroimaging studies (Cohen, Dehaene, Chochon, Lehericy, & Naccache, 2000) found that left frontal, inferior parietal, perisylvian region, and basal ganglia regions were all related to mathematical functions. Feifer and De Fina (2005) suggested that the region of the brain being activated varies depending upon the type of mathematical calculation being performed.

## Interpreting the WJ-IV From a Neuropsychological Perspective

Due to the page constraints of a book chapter, it is not possible to include a sample of a complete neuropsychological report, which integrates the WJ-IV tests as the core battery. However, it is possible to provide an example of how one section of learning and memory within a comprehensive neuropsychological evaluation could be examined from a neuropsychological perspective. Table 3 presents the WJ-IV tests that are classified according to the Integrated SNP/CHC Model (Miller, 2013) as measures of learning and memory. Table 3 also presents the demand characteristics of each of these tests.

In Table 3, note that three of the WJ-IV tests measure immediate verbal memory and recall: WJ-IV COG Memory for Words, WJ-IV OL Sentence Repetition, and WJ-IV COG Story Recall. Each of these tests has a verbal input requirement, but vary in their complexity. There is a marked increase in the quantity of verbal input as the tasks increase from presenting words in isolation, to words in sentences, and finally to entire paragraphs. As a result of the changes to the verbal input of these three tasks, the processing and output demands change, as well. Some examinees benefit from the additional semantic loading or contextual cues (e.g., memory for stories > memory for sentences > memory for words). Examinees with these results typically benefit from learning new material that can be related to broad thematic topics or points of reference.

Other examinees struggle with the additional verbal content or semantic loading (e.g., memory for words > memory for sentences > memory for stories). Examinees with these results learn best by memorizing small chunks of information in isolation and become quickly overwhelmed by too much verbal information. It may be the case that examinees with this type of learning profile are capable of learning more complex material, but most likely their poor attention processing is hindering their learning capabilities. Performance on these three measures is also sensitive to changes in the processing requirements related to attentional capacity. Examinees who have significant attentional processing difficulties often achieve average scores on the Memory for Words test but their performance suffers on the other two immediate verbal memory tests as the verbal complexity increases (Miller, 2013).

It is important for the clinician to evaluate other potential differences within the learning and memory domain, such as, the potential difference between the three tests that measure immediate verbal memory and performance on the WJ-IV COG Picture Recognition test, which measures immediate visual memory and recall. Deficits in auditory processing often cause, or are related to, deficits in verbal memory. Likewise, deficits in visual-spatial processing often cause, or are related to, deficits in visual memory. It is important for the clinician to evaluate both the verbal and visual modalities of immediate memory. Instructional implications will vary depending upon any performance differences between verbal and visual immediate memory tasks.

Finally, within the learning and memory domain, it is important for clinicians to evaluate the learning and memory capabilities when verbal and visual information must be associated with each other. Paired associative learning is a prerequisite skill for the acquisition of good reading skills (Miller, 2013). Some examinees will perform in the average range for learning and memory of verbal or visual information in isolation, but stumble on verbal-visual associative learning tasks. From a neuropsychological perspective, it is important for clinicians to understand the neurocognitive demands of the tasks as reported by the test authors, as well as, any variations in strategies that an individual examinee may employ during the completion of tasks. Although a comprehensive review of demands analysis is beyond the scope of the present chapter, a number of useful resources (e.g., Carroll, 1976; Floyd & Kranzler, 2012; Hale & Fiorello, 2004) are available for clinician's to consult. The ultimate goal of a comprehensive assessment is to determine the examinee's strengths and weaknesses and tailor subsequent evidence-based interventions.

Despite the illusion of orthogonality provided by psychometric interpretive frameworks (e.g., CHC), some have characterized attempts to disentangle the different features of cognition is akin to "slicing smoke" (Horn, 1991). Accordingly, we encourage clinicians to be mindful of the fact that all cognitive tasks require an examinee to utilize multiple neurocognitive abilities simultaneously. An integrated neuropsychological assessment and interpretive model, as we have articulated in the present chapter, potentially provides WJ-IV users with an evidence-based framework for making more clinically useful inferences about the multitude of quantitative and qualitative factors that mediate the performance that is observed on individual psychoeducational tasks.

**Summary**

Compared to all of the other major co-normed tests of cognitive abilities and academic achievement, the WJ-IV provides the most coverage across the classifications defined by the Integrated SNP/CHC Model. While the WJ-IV Batteries covers a comprehensive representation of the broad and narrow neurocognitive processes and skills as outlined in the Integrated SNP/CHC Model (Miller, 2013), administering only those tests does not constitute a comprehensive neuropsychological assessment. Some processing domains are not covered by the WJ-IV such as sensorimotor functions and other domains of processing, which are not covered in great detail, such as tests of attention or learning and memory. The WJ-IV Battery of tests typically serves as baseline testing for a more comprehensive neuropsychological assessment. Hypotheses about an examinee's strengths and weaknesses are generated based on the WJ-IV tests results and then the clinician chooses additional cross-battery assessments to validate or refute those hypotheses.

The WJ-IV authors missed an important opportunity to add to the clinical utility of their tests during the revision by not including more qualitative behaviors. Some qualitative behaviors are included in the WJ-IV ACH tests, but the authors and publisher do not include standardization sample base rates for those qualitative behaviors. It is valuable to have the capability of making statements such as, "only 16% of children of the same age as the examinee engaged in this qualitative behavior." A trained clinician can certainly note qualitative behaviors during task administrations, but the base rate data would have been invaluable, as well.

Finally, a word of caution must be made about test interpretation in general. Test developers try to create tests that maximize the measurement variance of a particular skill or cognitive process. However, in any measurement there will be error variance that must be accounted for as well, and construct irrelevant cognitive processes or skills that may also account for some of the reliable variance (Schneider, 2103). Just because an examinee is presented with a verbal task that requires working memory and a verbal output does not mean that the examinee will utilize those same cognitive processes to complete the task. An important step in any assessment is to administer tests in a standardized manner, but to then ask the examinee why certain tasks are more difficult for them than others, and why some tasks are easier than others. This allows the administrator to explore with the examinee what kinds of unique strategies were employed to complete the tasks. This qualitative information provides critical details as to the processes underlying the standardized score and is a foundational feature of modern neuropsychological assessment (c.f., Kaplan, 1990). When coupled together, the qualitative data with the outcome scores provides the clinician the ability to develop a more meaningful profile of the examinee's neurocognitive strengths and weaknesses.

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Table 1

*Coverage of the Basic Neurocognitive Constructs by the WJ-IV Tests of Cognitive Abilities, Oral Language, and Achievement*

| Integrated SNP/CHC Broad Classifications | Integrated SNP/CHC Second Order Classifications | WJ-IV Test | WJ-IV Battery |
|---|---|---|---|
| Basic sensorimotor functions | Lateral preference | | |
| | Sensory functions | | |
| | Fine motor functions | | |
| | Visual-motor integration skills | | |
| | Visual scanning/tracking (Indirect measures) | Pair Cancellation<br>Number-Pattern Matching (New) | Cognitive<br>Cognitive |
| | Gross motor functions | | |
| | Quantitative behaviors | | |
| Cognitive processes: Visuospatial | Visuospatial perception | | |
| | Visuospatial reasoning | Visualization (New) | Cognitive |
| Cognitive Processes: Auditory/ Phonological | Sound discrimination and Auditory/phonological processing | Sound Awareness<br>Nonword Repetition (New)<br>Phonological Processing (New)<br>Segmentation (New)<br>Sound Blending | Oral Language<br>Cognitive<br>Cognitive<br>Oral Language<br>Oral Language |
| Cognitive Processes: Learning and Memory | Rate of learning | | |
| | Immediate verbal memory | Memory for Words<br>Sentence Repetition<br>Story Recall | Cognitive<br>Oral Language<br>Cognitive |
| | Visual immediate memory | Picture Recognition | Cognitive |
| | Delayed verbal memory | | |
| | Delayed visual memory | | |
| | Verbal-visual associative learning and recall | Visual-Auditory Learning | Cognitive |

(continued)

(*Table 1 continued*)

| | | | |
|---|---|---|---|
| Cognitive Processes: Executive Functions | Cognitive flexibility | | |
| | Concept recognition and generation | | |
| | Problem solving, fluid reasoning, and planning | Concept Generation<br>Analysis/Synthesis<br>Number Matrices (New)<br>Number Series | Cognitive<br>Cognitive<br>Achievement<br>Cognitive |
| | Response inhibition | | |
| Facilitators/Inhibitors: Allocating and Maintaining Attention | Selective/focused and sustained attention | Pair Cancellation | Cognitive |
| | Attentional capacity | Sentence Repetition<br>Memory for Words<br>Story Recall | Oral Language<br>Cognitive<br>Cognitive |
| Facilitators/Inhibitors: Working Memory | Working memory | Object-Number Sequencing<br>Numbers Reversed<br>Verbal Attention (New) | Cognitive<br>Cognitive<br>Cognitive |
| Facilitators/Inhibitors: Speed, Fluency, and Efficiency of Processing | Performance fluency | Letter-Pattern Matching (New)<br>Number-Pattern Matching<br>Rapid Picture Naming | Cognitive<br>Cognitive<br>Cognitive |
| | Retrieval fluency | Retrieval Fluency | Cognitive |
| | Acquired knowledge fluency | Oral Reading (New)<br>Word Reading Fluency (New)<br>Sentence Reading Fluency<br>Sentence Writing Fluency (new)<br>Math Facts Fluency | Achievement<br>Achievement<br>Achievement<br>Achievement<br>Achievement |
| Acquired Knowledge: Acculturation Knowledge | Semantic memory (General information) | Oral Vocabulary<br>General Information | Cognitive<br>Cognitive |
| Acquired Knowledge: Language Abilities | Oral expression | Picture Vocabulary | Cognitive |
| | Receptive language (Listening Comprehension) | Oral Comprehension<br>Understanding Directions | Oral Language<br>Oral Language |

(continued)

(*Table 1 continued*)

| | | | |
|---|---|---|---|
| Acquired Knowledge: Reading Achievement | Basic reading skills: Phonological decoding | Letter-Word Identification | Achievement |
| | | Word Attack | Achievement |
| | Reading comprehension skills | Passage Comprehension | Achievement |
| | | Reading Recall (New) | Achievement |
| | | Reading Vocabulary | Achievement |
| Acquired Knowledge: Written Language Achievement | Written expression | Editing | Achievement |
| | Expository composition | Writing Samples | Achievement |
| | Orthographic spelling | Spelling | Achievement |
| | | Spelling of Sounds | Achievement |
| Acquired Knowledge: Mathematics | Mathematical calculations | Calculations | Achievement |
| | Mathematical reasoning | Applied Problems | Achievement |

Table 2

*Input, Processing, and Output Demands Required for WJ-IV Cognitive, Achievement, and Oral Language Tests Classified According to Miller's Integrated School Neuropsychological – CHC Conceptual Model*

| Test | Task Description | Narrow CHC Ability | Input Demands | Processing Demands | Output Demands | Primary Neuroanatomical Regions |
|---|---|---|---|---|---|---|
| | | | Cognitive Processes: Visuospatial (*Gv*) | | | |
| COG-7: Visualization | Identify two or more pieces that go together to form a complete target shape and ability to select the two sets of blocks that are rotated versions of the target pattern. | • Visualization (VZ) | Visual (objects on a page) | Visuospatial reasoning (recognizing spatial configurations with and without mental rotations) | Verbal (stating numbers of correct answers) or motor response (pointing to correct answers) | Bilateral frontal-parietal network (mental rotations); right occipital-temporal region - ventral stream (recognition of objects) |
| | | | Cognitive Processes: Auditory/Phonological (*Ga*) | | | |
| COG-5: Phonological Processing | Three part task involving phonemic word recall, word retrieval, and phonemic substitution. | • Phonetic Coding (PC)<br>• Speed of Lexical Access (LA) | Verbal (words) | Phonological processing | Verbal (creation of words based on phonetic rules, word retrieval, and phonetic substitution | Bilateral posterior–superior temporal |
| COG-12: Nonword Repetition | Listen to a nonsense word then repeat it exactly. | • Phonetic Coding (PC)<br>• Memory for Sound Patterns (UM)<br>• (Auditory) Memory Span (MS) | Verbal (nonsense words) | Phonological processing in verbal immediate memory | Verbal (nonsense word) | Ventral aspect of the inferior parietal cortex |
| OL-3: Segmentation | Listens to words and identifies word parts. | • Phonetic Coding (PC) | Verbal (segmented words) | Phonological processing | Verbal (parts of words or whole words) | Bilateral posterior–superior temporal |

(continued)

(*Table 2 continued*)

| | | | | | | |
|---|---|---|---|---|---|---|
| OL-7: Sound Blending | Identifying a whole word base on the sum of the individual phonemes. | • Phonetic Coding (PC) | Verbal (phonemes) | Phonological processing | Verbal (word) | Bilateral posterior–superior temporal |
| OL-9: Sound Awareness | Deleting word parts and phonemes from orally presented words. | • Phonetic Coding (PC) | Verbal (words and phonemes) | Phonological processing | Verbal (words and phonemes) | Bilateral posterior–superior temporal |
| | | | Cognitive Processes: Learning and Memory (*Glr*) | | | |
| COG-6: Story Recall | Details recalled from verbally presented stories. | • Meaningful Memory (MM)<br>• Listening Ability (LS) | Verbal (passages) | Immediate verbal memory and recall. | Verbal (passage) | Anterior temporal lobes, dorsomedial prefrontal cortex, and areas along the middle and superior temporal gyri and inferior frontal cortex. |
| COG-13: Visual-Auditory Learning | Learning visual-verbal associations and then recalling them. | • Associative Memory (MA) | Paired visual (rebuses) and auditory (words) | Verbal-visual associative learning and recall. | Verbal (words to form sentences) | Left fusiform gyrus and left inferior parietal lobe |
| COG-14: Picture Recognition | Identifying previously seen pictures embedded in a set of similar pictures. | • Visual Memory (MV) | Visual (pictures) | Immediate visual memory and recall. | Verbal (numbers of pictures) or motoric (pointing to pictures | Left ventrolateral prefrontal cortex |
| COG-18: Memory for Words | Repeat a list of unrelated words in sequence. | • Memory Span (MS) | Verbal (words) | Immediate verbal memory and recall. | Verbal (sequence of words) | Right dorsolateral frontal cortex and the bilateral posterior parietal cortex |
| OL-5: Sentence Repetition | Recall of sentences of increasing length and complexity. | • Memory Span (MS)<br>• Listening Ability (LS) | Verbal (sentences) | Immediate verbal memory and recall. | Verbal (sentences) | Right dorsolateral frontal cortex and the bilateral posterior parietal cortex |
| | | | Cognitive Processes: Executive Functions (*Gf*) | | | |
| COG-2: Number Series | Determining a number missing in a sequence. | • Quantitative Reasoning (RQ)<br>• Induction (I) | Visual (numeric) | Recall and manipulation of internal number line and applying numerical reasoning to solve problem. | Verbal (a number). | Horizontal intraparietal sulcus within the parietal cortex (number sense) and left-frontal parietal and left basal ganglia (reasoning). |

(continued)

(*Table 2 continued*)

| | | | | | | |
|---|---|---|---|---|---|---|
| COG-9: Concept Formation | Determining and applying categorization rules. | • Induction (I) | Visual (drawings) | Executive functions of categorization based on rules using inductive reasoning. | Verbal (definition of a conceptual rule). | Prefrontal-striatal-thalamus loop. |
| COG-15: Analysis-Synthesis | Analyzing if then visual relationships to deduce missing elements. | • General Sequential Reasoning (RG) | Visual (drawings) | Executive functions of deductive reasoning. | Verbal (words). | Left-frontal parietal and left basal ganglia. |
| ACH-13: Number Matrices | Ability to analyze the relationship among numbers and identify the missing number. | • Quantitative Reasoning (RQ) | Visual (numeric) | Fluid reasoning: quantitative reasoning. | Verbal (a number) | Horizontal intraparietal sulcus within the parietal cortex (number sense) and left-frontal parietal and left basal ganglia (reasoning). |
| | | | Facilitators/Inhibitors: Allocating and Maintaining Attention | | | |
| COG-17: Pair Cancellation | Matching target stimuli from a large visual array under time constraints. | • Attentional Control (AC)<br>• Perceptual Speed (P)<br>• Spatial Scanning (SS) | Visual (picture icons) | Selective/focused and sustained attention; proactive interference | Motoric (circle responses) | Right prefrontal and anterior cingulate. |
| | | | Facilitators/Inhibitors: Working Memory | | | |
| COG-3: Verbal Attention | Answering questions about the order of intermingled list of animals and digits. | • Working Memory Capacity (WM)<br>• Attentional Control (AC) | Verbal (words and numbers) | Verbal working memory and attentional capacity | Verbal (animal name or digit) | Left supramarginal gyrus in the inferior parietal lobes and the lateral frontal (premotor) region |
| COG-10: Numbers Reversed | Holding a span of numbers in immediate memory then performing a mental operation on them. | • Working Memory Capacity (WM)<br>• Attentional Control (AC) | Verbal (numbers) | Short-term verbal working memory and attentional capacity. | Verbal (number sequence) | Left supramarginal gyrus in the inferior parietal lobes and the lateral frontal (premotor) region |
| COG-16: Object-Number Sequencing | Holding a set of intermingled words and numbers in memory than recall them regrouped into ordered sequences. | • Working Memory Capacity (WM) | Verbal (words and numbers) | Verbal working memory and recall. | Verbal (number or word sequence) | Left supramarginal gyrus in the inferior parietal lobes and the lateral frontal (premotor) region |

(continued)

(*Table 2 continued*)

| | | | | | | |
|---|---|---|---|---|---|---|
| Facilitators/Inhibitors: Speed, Fluency, and Efficiency of Processing - Cognitive Processing Speed (*Gs*) | | | | | | |
| COG-4: Letter-Pattern Matching | Locate and circle two identical letter patterns in a row. | • Perceptual Speed (P) | Visual (letters on a page). | Perceptual speed, a function of processing speed | Motoric (circle items on a page). | White matter organization in parietal and temporal lobes and connections to lateral prefrontal cortex. |
| COG-11: Number-Pattern Matching | Locate and circle two identical numbers in a row of numbers. | • Perceptual Speed (P) | Visual (numbers on a page). | Perceptual speed, a function of processing speed | Motoric (circle items on a page). | White matter organization in parietal and temporal lobes and connections to lateral prefrontal cortex. |
| OL-4: Rapid Picture Naming | Naming quickly pictures of common objects across rows. | • Naming Facility (NA)<br>• Speed of Lexical Access (LA) | Visual (Pictures) | Speed of lexical access | Verbal (words) | Left temporal lobe (lexical access) |
| OL-8: Retrieval Fluency | Naming words as quickly as possible, which start with a particular letter or fit in the same category. | • Ideational Fluency (FI)<br>• Speed of Lexical Access (LA) | Auditory (directions only) | Speed of word and semantic lexical assess | Verbal (words) | Left temporal lobe (lexical access) |
| ACH-8: Oral Reading | Reading sentence for accuracy and fluency of expression of increasing lengths and difficulty. | • Reading Decoding (RD)<br>• Verbal (printed) Language Comprehension (V) | Visual (sentences) | Reading fluency: rapid phonological decoding | Verbal (sentences) | Left occipital and fusiform gyrus (fluency) |
| ACH-9: Sentence Reading Fluency | Rapidly reading short, simple sentences and circles yes or no if they make sense over a 3-minute interval. | • Reading Speed (RS)<br>• Reading Comprehension (RC) | Visual (sentences) | Reading fluency: rapid phonological decoding | Verbal (sentences) | Left occipital and fusiform gyrus (fluency); right inferior longitudinal fasciculus and the superior longitudinal fasiculus (reading comprehension). |
| ACH-11: Sentence Writing Fluency | Producing, in writing, simple sentences that are legible. | • Writing Speed (WS)<br>• Writing Ability (WA) | Auditory (directions and prompts) | Writing fluency | Motoric (written sentences) | Left basal ganglia |
| ACH-10: Math Facts Fluency | Solving simple math problems quickly. | • Mathematic Achievement (A3)<br>• Number Facility (N) | Visual (math problems) | Mathematics fluency | Motoric (solving math problems) | Horizontal segment of the intraparietal sulcus |

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(*Table 2 continued*)

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|---|---|---|---|---|---|---|
| ACH-15: Word Reading Fluency | Rapidly reading words and marking the two semantically related words in each row. | • Reading Comprehension (RC)<br>• Reading Speed (RS) | Visual (words) | Reading fluency | Motoric (slash marks) | Left occipital and fusiform gyrus (fluency) |
| | | | Acquired Knowledge: Acculturation Knowledge | | | |
| COG-1: Oral Vocabulary | Knowledge of synonyms and antonyms. | • Lexical Knowledge (VL)<br>• Language Development (LD) | Auditory questions | Semantic memory activation and retrieval and verbal analogical reasoning. | Verbal (saying a word). | Middle temporal gyrus and inferior temporal gyrus. |
| COG-8: General Information | Knowledge of what and where questions. | • General Verbal Information (K0) | Auditory questions | Semantic memory activation and retrieval from declarative (semantic) memories. | Verbal (one word or up to a sentence answer). | Inferior frontal gyrus and the anterior cingulate |
| ACH-18: Science | Knowledge of information related to science. | • General Verbal Information (K0)<br>• General Science Information (K1) | Auditory questions with visual stimuli | Semantic memory of domain-specific knowledge | Verbal | Inferior frontal gyrus and the anterior cingulate |
| ACH-19: Social Studies | Knowledge of information related to social studies. | • General Verbal Information (K0)<br>• Knowledge of Culture (K2)<br>• Geography Achievement (A5) | Auditory questions with visual stimuli | Semantic memory of domain-specific knowledge | Verbal | Inferior frontal gyrus and the anterior cingulate |
| ACH-20: Humanities | Knowledge of information related to humanities and the arts. | • General Verbal Information (K0)<br>• Knowledge of Culture (K2) | Auditory questions with visual stimuli | Semantic memory of domain-specific knowledge | Verbal | Inferior frontal gyrus and the anterior cingulate |
| | | | Acquired Knowledge: Language Abilities | | | |
| OL-1: Picture Vocabulary | Recognize and name pictured objects. | • Lexical Knowledge (VL)<br>• Language Development (LD) | Visual (picture) | Oral expression: vocabulary knowledge | Verbal (word) | Left prefrontal cortex, with contributions from the temporal, anterior cingulate, and cerebellum. |

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|---|---|---|---|---|---|---|
| OL-2: Oral Comprehension | Listening to a short passage and providing the missing word. | • Listening Skills (LS) | Verbal listening skills. | Receptive language and semantic memory activation and retrieval. | Verbal (missing word). | Left hemisphere temporoparietal region “Wernicke area” and left prefrontal cortex (retrieval). |
| OL-6: Understanding Directions | Listening to instructions and then pointing to objects in pictures. | • Working Memory Capacity (WM)<br>• Listening Skills (LS) | Verbal listening skills | Verbal working memory and receptive language skills. | Nonverbal “pointing” response. | Left hemisphere temporoparietal region “Wernicke area” and left supramarginal gyrus in the inferior parietal lobes. |
| | | | Acquired Knowledge: Reading Achievement | | | |
| ACH-1: Letter-Word Identification | Reading words in isolation. | • Reading Decoding (RD) | Verbal (words) | Basic reading skills: phonological decoding | Verbal (words) | Left inferior frontal and inferior parietal |
| ACH-7: Word Attack | Reading phonetically regular nonsense words orally. | • Reading Decoding (RD)<br>• Phonetic Coding (PC) | Verbal (nonsense words) | Basic reading skills: phonological decoding | Verbal (nonsense words) | Supramarginal gyrus |
| ACH-4: Passage Comprehension | Reading a passage silently and provides the missing word. | • Reading Comprehension (RC) | Visual (reading passages) | Reading comprehension skills | Verbal (word) | Right inferior longitudinal fasciculus (ILF) and superior longitudinal fasciculus (SLF) tracts |
| ACH-12: Reading Recall | Ability to read a story silently and retell as much of the story as possible. | • Reading Comprehension (RC)<br>• Meaningful Memory (MM) | Visual (reading passages) | Reading comprehension skills | Verbal (story recall) | Right inferior longitudinal fasciculus (ILF) and superior longitudinal fasciculus (SLF) tracts |
| ACH-17: Reading Vocabulary | Orally producing synonyms, antonyms, or verbal analogies. | • Reading Comprehension (RC)<br>• Lexical Knowledge (VL) | Verbal (directions and prompts) with visual (word cues) | Reading comprehension skills | Verbal (word) | Right inferior longitudinal fasciculus (ILF) and superior longitudinal fasciculus (SLF) tracts |

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|---|---|---|---|---|---|---|
| | | | Acquired Knowledge: Written Language Achievement | | | |
| ACH-14: Editing | Ability to use proper punctuation and capitalization and identify writing mistakes. | • English Usage (EU) | Visual (sentences) | Written expression skills | Oral (editing details) | Left pre-frontal (retrieval) |
| ACH-6: Writing Samples | Producing meaningful written sentences. | • Writing Ability (WA) | Verbal (directions) and visual (text) | Expository composition skills | Motoric (writing) | Cerebellum and frontal areas of language-dominant hemisphere |
| ACH-3: Spelling | Ability to spell words from dictation. | • Spelling Ability (SG) | Verbal (words) | Orthographic spelling skills | Motoric (writing) | Left fusiform gyrus, left supramarginal gyrus, and inferior frontal cortex |
| ACH-16: Spelling of Sounds | Ability to spell nonsense words that conform to conventional phonetics. | • Spelling Ability (SA)<br>• Phonetic Coding (PC) | Verbal (letters and words) | Orthographic spelling skills | Motoric (writing) | Left fusiform gyrus, left supramarginal gyrus, and inferior frontal cortex |
| | | | Acquired Knowledge: Mathematics Achievement | | | |
| ACH-5: Calculations | Performing a variety of math calculations. | • Mathematical Achievement (A3) | Visual (numbers) | Mathematical calculation skills | Motoric (writing) | <u>Addition and multiplication Facts</u>: Left perisylvian area along the temporal lobe<br><u>Subtraction</u>: Bilateral occipital-temporal regions<br><u>Number recognition</u>: fusiform gyrus<br><u>Estimation skills, fractions, and Division</u>: bilateral inferior parietal regions |
| ACH-2: Applied Problems | Analyzing and solving practical math problems. | • Mathematical Achievement (A3)<br>• Quantitative Reasoning (RQ) | Verbal (questions) and Visual (numbers and text) | Mathematical reasoning skills | Verbal (answers) | Horizontal intraparietal sulcus within the parietal cortex (number sense) and left-frontal parietal and left basal ganglia (reasoning). |

Table 3

*Example of a Demand Analysis for the WJ-IV Learning and Memory Tests*

| Test | Task Description | Input Demands | Processing Demands | | Output Demands |
|---|---|---|---|---|---|
| COG-18: Memory for Words | Repeat a list of unrelated words in sequence. | Verbal (words) | Immediate verbal memory and recall. | Increased contextual cues and semantic loading | Verbal (sequence of words) |
| OL-5: Sentence Repetition | Recall of sentences of increasing length and complexity. | Verbal (sentences) | Immediate verbal memory and recall. | | Verbal (sentences) |
| COG-6: Story Recall | Details recalled from verbally presented stories. | Verbal (passages) | Immediate verbal memory and recall. | | Verbal (passage) |
| COG-13: Visual-Auditory Learning | Learning visual-verbal associations and then recalling them. | Paired visual (rebuses) and auditory (words) | Verbal-visual associative learning and recall. | | Verbal (words to form sentences) |
| COG-14: Picture Recognition | Identifying previously seen pictures embedded in a set of similar pictures. | Visual (pictures) | Immediate visual memory and recall. | | Verbal (numbers of pictures) or motoric (pointing to pictures |