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Assessment of Executive Functions Using the *Woodcock-Johnson® IV Tests of Cognitive Abilities*

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Executive functions are higher-order neurocognitive abilities involved in goal-directed actions and are important for planning, judgment, reasoning, and problem solving. Executive functions have been one of the most studied constructs in neuropsychology over the past 20 years, and executive dysfunction has been implicated in a number of neurological and psychiatric disorders. The degree to which executive functioning (EF) influences the ability to complete tasks varies on different measures of intelligence and cognition. The purpose of this Assessment Service Bulletin is to provide general guidance for understanding the relationship between executive functions and cognitive constructs measured in the Woodcock-Johnson IV Tests of Cognitive Abilities *(Schrank, McGrew, & Mather, 2014b).*

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Assessment of Executive Functions Using the *Woodcock-Johnson® IV Tests of Cognitive Abilities*

Executive functions (EF) is a term used to describe a set of higher-level cognitive functions important for implementing and sustaining goal-directed behavior and complex problem solving. Executive functions are essential for many cognitive, emotional, and social skills because they represent abilities used to respond adaptively to novel situations (Lezak, Howieson, Bigler, & Tranel, 2012) as well as control and regulate lower-level cognitive processes (Alvarez & Emory, 2006). Executive functions are multidimensional and encapsulate a wide array of measurable human behaviors. Consequently, universal agreement has not yet been reached about which abilities underlie this umbrella term. However, EF measures most commonly include abilities relating to behavioral inhibition, task switching, working memory (WM), and sustained and selective attention (Alvarez & Emory, 2006), often under goal-oriented conditions involving volition, planning and decision making (Lezak et al., 2012).

Deficits in EF were first found to be associated with frontal lobe injuries in the brain (Halstead, 1947; Luria, 1973, 1980) as well as developmental changes in the brain (Diamond, 2001, 2002; Golden, 1981), although more recent research shows that multiple neurological areas contribute to executive functioning (Niendam et al., 2012). For instance, recent neuroimaging studies suggest a functional relationship between the cerebellum, basal ganglia, and other subcortical structures and executive functioning (Heilbronner & Haber, 2014; Niendam et al., 2012; Riva, Cazzaniga, Esposito, & Bulgheroni, 2013).

Children's performance on EF tasks rapidly improves between ages 4 and 6 years, possibly due to biological maturation and/or increased opportunity for social experiences (e.g., beginning school; Carlson, 2005; Espy, Kaufmann, McDiarmid, & Glisky, 1999; Sowell, Trauner, Gamst, & Jernigan, 2002). Executive dysfunction or delay has been associated with a wide range of disorders including attention-deficit/hyperactivity disorder (ADHD; Martel, Nikolas, & Nigg, 2007; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005), autism spectrum disorders (ASD; Chen et al., 2016; Pennington & Ozonoff, 1996), traumatic brain injury (Beauchamp et al., 2011), frontotemporal dementia (Hodges, 2001; Wittenberg et al., 2008), Lewy body dementia (Johns et al., 2009), Parkinson's disease (Cools, Barker, Sahakian, & Robbins, 2001; McKinlay, Grace, Dalrymple-Alford, & Roger, 2010; Zgaljardic et al., 2006), Huntington's disease (Brandt et al., 2008), small vessel ischemic disease (Carey et al., 2008), emotional and social competence (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Rhoades, Greenberg, & Domitrovich, 2009), behavioral control (Eisenberg, Fabes, & Losoya, 1997; Eisenberg et al., 2005), social cognition (Carlson, Moses, & Breton, 2002; Perner & Lang, 1999), school adjustment (Blair, 2002; Bodrova & Leong, 2006), and academic achievement (Best, Miller, & Naglieri, 2011; Bull & Scerif, 2001; Duncan et al., 2007).

There is also growing recognition of the importance of EF in social functioning (Blain-Briere, Bouchard, & Bigras, 2014). In fact, some researchers have postulated that evolutionary social demands have had a genetic influence on the size and functional connectivity of the frontal lobes in humans (Dumontheil, 2014; Matsuzawa, 2013; Stout, 2010; Teffer & Semendeferi, 2012). Social deficits often emerge from executive dysfunction, and individuals with frontal lobe injuries often display both EF and social deficits (Dishion, 2016; Dumontheil, 2014). The relationship between social deficits and EF likely is based on the advanced cognitive demands inherent in social interactions. Because positive social interactions may involve rapid processing of socially relevant information and inhibiting impulsive actions, deficits in EF will likely impair the quality of social interactions. Inhibition is a critical component of executive functioning, and difficulty holding back automatic responses can result in age-inappropriate social behavior.

Components of Executive Functioning

Despite its importance, there are no comprehensive models of EF that provide a unified framework for integrating all the behaviors associated with EF. However, numerous theories have been postulated to explain the behavioral deficits associated with frontal lobe injuries (Barkley, 1997, 2001; Lezak, 1995; Miller, 2005; Pennington, 2009). Because traditional theories focus on the role of EF in novel problem solving (Stuss & Benson, 1986; Zelazo, Carter, Reznick, & Frye, 1997), working memory has long been a vital construct associated with EF. In fact, working memory has been viewed as the core of EF and the basis for understanding behavioral deficits frequently seen in clinical populations (Barkley, 1997, 2001). The degree to which EF and WM can be differentiated is unclear and may vary by how these constructs are defined. For example, some studies have found high correlations between tasks purported to measure EF and tasks purported to measure WM, indicating a possible latent variable—attention—underlying both EF and WM constructs (Decker, Hill, & Dean, 2007; Kane & Engle, 2002; McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). Additionally, neuroimaging studies have shown that a common neurological substrate in the prefrontal cortex is implicated in WM and EF tasks, further suggesting a common variable between the two constructs (Kane & Engle, 2002; Sauseng, Klimesch, Schabus, & Doppelmayr, 2005). Regardless of a common variable, the ability to hold and manipulate both auditory and visual stimuli in working memory is key to the successful execution of a variety of functions.

Several studies have attempted to identify the underlying components common to various EF measures. These studies primarily investigated the statistical relationship of EF measures with other cognitive constructs, primarily using factor and confirmatory factor analytic techniques (Lee, Bull, & Ho, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000; Stuss & Alexander, 2000) as well as canonical correlation (Davis, Pierson, & Finch, 2011; Roberds, 2015). For example, Decker et al. (2007) investigated a battery of EF measures in relation to constructs in the Cattell-Horn-Carroll (CHC) model of intelligence (Carroll, 1993), as measured by the *Woodcock-Johnson Psycho-Educational Battery–Revised Tests of Cognitive Ability* (Woodcock & Johnson, 1989). This study found that latent constructs of EF were highly similar, if not identical, to latent constructs of fluid reasoning (FR). Fluid reasoning can be defined as the analytic ability utilized for resolving novel problems, or problems that cannot be solved via reference of stored knowledge (Cattell, 1963). Similar results have been found in other studies using analogous constructs (Kane & Engle, 2002; Kyllonen & Christal, 1990; Richland & Burchinal, 2013). Given definitional similarities between FR and EF, the high association between these constructs is not surprising.

Several other studies have identified specific EF components that include inhibition, attention flexibility (set-shifting), and WM (Lehto et al., 2003; Miyake et al., 2000). Other studies using factor analytic methodologies have identified problem solving, planning, and speeded responding (fluency) as specific aspects of EF (Levin et al., 1991; Welsh, Pennington, & Groisser, 1991). More recently, Decker, Ezrine, and Ferraracci (2016) conducted a factor analytic study of EF measures in preschool children and found WM and cognitive flexibility (as related to language) were the primary latent dimensions measured by different EF tests.

Given the general influence EF may have across different domains of cognition, a key consideration in the practice of school psychology is the degree to which EF influences scores on specific measures of cognitive ability. This question is paramount, given that school psychologists, perhaps as a result of time restraints, may not include standalone measures of executive functioning in their assessment batteries. However, intelligence tests are generally included in most assessments, and, thus, school psychologists may infer executive dysfunction from performance on intelligence tests.

The research on the relationship between EF and intelligence has been somewhat mixed and, in part, depends upon the type of both the EF measure as well as the intelligence test. Davis et al. (2011) evaluated the canonical relationship between performance on the *Wechsler Adult Intelligence Scale®–Third Edition* (WAIS®-III; Wechsler, 1997) and the tests of the *Delis-Kaplan Executive Function System*™ (D-KEFS™; Delis, Kaplan, & Kramer, 2001). The authors found that despite shared variability, the EF tests had unique variability when compared with global intelligence. Similarly, Roberds (2015) found that when select tests of the *Woodcock-Johnson III Tests of Cognitive Abilities* (WJ III® COG; Woodcock, McGrew, & Mather, 2005) were compared with the Color-Word Interference Test and the Tower Test from the D-KEFS, a relationship emerged between executive functioning and cognitive processing, although each measure maintained unique variance. Canonical correlation analysis indicated approximately one third of the variation in performance on one of the measures could be accounted for by performance on the other measure. Linear regression modeling showed select tests from the WJ III COG were predictive of performance on EF tasks; however, a substantial portion of the variance between performance on the WJ III COG and the D-KEFS was unaccounted for in this analysis. These findings suggest EF is related to specific cognitive measures that may be included in a comprehensive assessment of intellectual functioning; however, intelligence tests do not fully capture EF as a construct.

Theoretically based qualitative analysis is also a useful approach for understanding EF components of different cognitive tasks. There are likely many cognitive abilities that are highly related to EF, and many that are not. EF measures will likely be related to cognitive tests that involve self-regulation of effort. As such, EF will likely be more related to confrontational measures that require *Gf* and WM to successfully complete, as previously supported by research, than to Comprehension-Knowledge (*Gc*) tasks that require associated knowledge or knowledge retrieval. However, self-regulation of cognitive effort is only one component of EF. EF also is defined by the capacity to inhibit behavior, which is weakly represented in most FR measures. In essence, the relationship between EF and other cognitive constructs is facilitated by identifying the underlying components inherent in the specific measures of each construct.

The underlying components of EF are not completely understood; however, some general themes can be derived from a review of research. Table 1 provides a systematic review of research within the last 10 years that included measures of EF components.

Table 1.
Studies Examining Components of EF in Younger Populations, 2006 through 2015

Study	Inhibition	WM	Cognitive Flexibility	Subjects
Monette et al. (2015)	Stroop	Backward Span	Trails-P, Card Sort, Fluency, Face Sort	*n* = 275 Age 5
Howard et al. (2015)	Go/No-Go	Backward Span	DCCS	*n* = 281 Ages 3–4
Brocki et al. (2014)	Stroop, Go/No-Go, Flanker	Recall, Backward Span	Dots	*n* = 114 Ages 5–14
Usai et al. (2014)	Motor Inhibition, Tower of London	Backward Span	Fluency, DCCS	*n* = 125 Ages 5–7
Lee et al. (2013)	Flanker, Simon Task, Selective Attention Task	Recall	Picture-Symbol	*n* = 668 Ages 5–15
Ven et al. (2013)	Stroop, Local-Global, Simon Task	Backward Span, Odd One Out, Keep Track	Animal Shifting, Trail Making Test (color), Sorting Task	*n* = 211 Ages 5–7
Lee et al. (2012)	Simon Task, Flanker	Recall	Simon Task and Flanker (switching conditions), Picture-Symbol	*n* = 163 Age 6
Miller et al. (2012)	Preschool CPT, Tower of Hanoi, Go/No-Go	Backward Span, Recall	Preschool CPT, Go/No-Go, ADCCS	*n* = 129 Ages 3–5
Fuhs et al. (2011)	Stroop	—	FIST, Spatial Reversal	*n* = 132 Ages 3–5
McAuley et al. (2011)	Go/No-Go, Response Compatibility Task	Recall, Backward Span	—	*n* = 147 Ages 6–24
Rose et al. (2011)	Go/No-Go, Preschool CPT	Recall	Trail Making Test, ID/ED Shift	*n* = 134 Age 11
Wiebe et al. (2011)	Stroop, Go/No-Go, Motor Inhibition, Shape-School	Recall, Delayed Alternation	—	*n* = 228 Age 3
Hughes et al. (2009)	Stroop	Recall	—	*n* = 191 Age 6
Shing et al. (2010)	Simon Task	Abstract Shapes	—	*n* = 263 Ages 4–14
Wiebe et al. (2008)	Motor Inhibition, Shape-School, Tower of Hanoi, Preschool CPT	Delayed Alternation, Recall	—	*n* = 243 Ages 2–6
van der Sluis et al. (2007)	Interference Control, Local-Global, Stroop	Recall	Alternating Response Tasks, Trail Making Test	*n* = 172 Ages 9–12
Huizinga et al. (2006)	Motor Inhibition, Stroop	Recall	Local-Global	*n* = 384 Ages 7, 11, 15, 21

Note. The measures listed in this table are broadly defined and do not include all of the details of each test (e.g., Recall variations: digit, word, spatial, selective, *n*-back, etc.; Stroop variations: color-word, knock-tap, day-night, etc.).

DCCS = Dimensional Change Card Sort; ADCCS = Advanced Dimensional Change Card Sort (also known as *border version*); CPT = Continuous Performance Test; FIST = Flexible Item Selection Task; ID/ED = Intradimensional/Extradimensional (CANTAB Assessment).

The table includes the three most widely considered EF components and the measures each study used to operationally define them. Given that childhood has been known to be a period of rapid EF development, our research review emphasized younger populations.

Across a variety of research studies, EF has been most frequently defined by three underlying components: inhibition, working memory, and cognitive flexibility. Although not exhaustive, these three constructs of EF provide a reasonable framework for investigating the EF demands of tests that purport to primarily measure other constructs. It is important to reiterate that there are other widely accepted constructs, such as planning, judgment, organization, and reasoning, that are also associated with executive functioning; however, these may not be as widely discussed, particularly in relationship to their measurement on cognitive tests and their contribution to psychiatric and academic problems.

To investigate the EF demands of the *Woodcock-Johnson IV Tests of Cognitive Abilities* (WJ IV™ COG; Schrank, McGrew, & Mather, 2014b), we reviewed the task demands of each test on the WJ IV COG and determined the degree to which cognitive demands included inhibition, working memory, and cognitive flexibility. In light of the recent publication of the WJ IV COG, independent studies are needed to explore the underlying construct validity of each of these tests; however, given that they are based on well-validated measures and theories, it is possible to extrapolate information from the literature.

What Constructs Are Measured by the WJ IV COG?

The *Woodcock-Johnson IV* (WJ IV; Schrank, McGrew, & Mather, 2014a) is a multidimensional battery of cognitive, language, and achievement tests. This review focuses on the tests in the cognitive battery. The cognitive measures are based on the Cattell-Horn-Carroll model of intelligence (Carroll, 1993; McGrew, LaForte, & Schrank, 2014; Schrank, Decker, & Garruto, 2016). The CHC model is a hierarchical model of intelligence derived from psychometric and statistical analysis of the interrelationships of behavioral measures of cognition. The CHC model consists of three strata, or levels, of cognitive abilities, including general intelligence (*g*), broad abilities, and narrow abilities. There is some debate as to the importance of assessing *g* when applying CHC theory, as some believe the utility of the model is in the use of the broad and narrow cognitive abilities to assess individuals' strengths and weaknesses (Flanagan, Ortiz, & Alfonso, 2013). Additionally, the broad and narrow abilities have been shown to account for a significant portion of the variance in academic outcomes, beyond that which is accounted for by *g* (Floyd, McGrew, & Evans, 2008; McGrew, Flanagan, Keith, & Vanderwood, 1997; Vanderwood, McGrew, Flanagan, & Keith, 2002). Because of the empirical support and predictability of the constructs outlined in CHC theory, it has continued to be used as a framework for interpreting cognitive test results (Flanagan et al., 2013). Furthermore, CHC theory is the basis for many modern measures of intelligence and cognitive processing (Alfonso, Flanagan, & Radwan, 2005; Keith & Reynolds, 2010).

Which WJ IV COG Tests Assess EF?

Table 2 provides a qualitative evaluation of each WJ IV COG measure and its potential EF involvement. Although no formal studies have specifically evaluated the relationship between EF measures and the WJ IV COG, the table provides a theoretical correspondence between EF components and cognitive components measured by the WJ IV COG tests.

Table 2.
Influences of Executive Functions in WJ IV COG Tests

WJ IV COG Test	Inhibition	WM	Cog Flex	Overall Relation to EF
Test 1: Oral Vocabulary	–	–	–	None
Test 2: Number Series	–	+	–+	Holding information in mind to find and adapt to new patterns
Test 3: Verbal Attention	+	+	–	Short-term memory and sustained attentional demands
Test 4: Letter-Pattern Matching	–+	–	–	Resistance to distraction
Test 5: Phonological Processing	–	–	–+	Shifting demands (only in Word Fluency measure)
Test 6: Story Recall	–	–+	–	Auditory memory
Test 7: Visualization	–	+	–	Visualizing manipulated information
Test 8: General Information	–	–	–	None
Test 9: Concept Formation	–	–+	–+	Holding information in mind and shifting inductive reasoning to learn changing rules
Test 10: Numbers Reversed	–	+	–	Manipulating order of number sequences
Test 11: Number-Pattern Matching	–+	–	–	Resistance to distraction
Test 12: Nonword Repetition	–	–	–	None
Test 13: Visual-Auditory Learning	–	–+	–	Remembering meaning with or without feedback
Test 14: Picture Recognition	–+	–	–	Resistance to distraction
Test 15: Analysis-Synthesis	–	–	–+	Memory with changing demands
Test 16: Object-Number Sequencing	–	+	–+	Holding information in mind and ordering different sequences
Test 17: Pair Cancellation	–+	–	–	Resistance to distraction
Test 18: Memory for Words	–	–+	–	Word recall

– = little to no EF involvement. EF deficits may have little impact on overall score.
–+ = some EF involvement in certain aspects of task.
+ = high EF involvement. EF deficit may have major impact on overall score.

Select EF Constructs

Inhibition. Inhibition is the ability to monitor and disengage automatic behavioral responses in favor of situationally appropriate responses (Miyake et al., 2000). Inhibition requires immediate discontinuation of ongoing behavior to learn, understand, or comprehend the directions or rules of a particular task. Attention is thought to be partly dependent on the ability to inhibit other stimuli or conflicting cognitive processes, meaning tasks that involve resistance to distraction may also involve inhibition. Thus, to be considered a component of EF, the inhibition demands must be beyond those of the general understanding of the directions of a test, must be involved in the success of each item, or must require some level of selective attention.

Working Memory. The earliest research on WM focused on the ability to compile information in short-term storage, maintain select information from the storage in immediate awareness, and manipulate the actively maintained information, ultimately for the purpose of reasoning and comprehension (Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Broadbent, 1958). Research has since expanded upon the WM construct and assumes several elements in the model (Baddeley, 2000), and when measuring EF abilities, studies assess WM by performance on its two overall functions, maintenance of information (updating) and manipulation. Cognitive tasks were rated positively on WM demands if the task performance required maintaining and updating information in memory according to some specified rule, especially for instances in which updating/manipulation is used for conceptual formations and pattern identification.

Cognitive Flexibility. Cognitive flexibility is the ability to shift or adapt cognitive representations and/or attention to match changing situational demands (Deak, 2004). Cognitive tasks were rated positively on cognitive flexibility if the task involved the shifting and changing of cognitive representations across successive items within the test.

Woodcock-Johnson IV Tests of Cognitive Abilities and EF Involvement

This section discusses the involvement of EF components in the tests of the WJ IV COG. Table 2 indicates the WJ IV COG tests that most likely require an element of EF. The appendix on page 19 provides a brief description of each WJ IV COG test and the associated CHC factors and ability clusters. Readers interested in a complete description and interpretation of the tests are directed to the *Woodcock-Johnson IV Tests of Cognitive Abilities Examiner's Manual* (Mather & Wendling, 2014) and to Schrank et al. (2016).

Test 1: Oral Vocabulary. The successful execution of this test requires minimal inhibition, working memory, or cognitive flexibility because it primarily relies upon crystallized knowledge and receptive and expressive language. Theoretically, however, EF deficits could result in difficulty acquiring this knowledge via associated functional concerns (e.g., academics, social skills).

Test 2: Number Series. This measure of fluid reasoning is considered complex, and successful completion relies upon EF, quantitative reasoning, deduction, and induction (Schrank et al., 2016). The executive functions involved in this test include cognitive flexibility (to change strategies) and working memory (to hold on to information while seeking an answer).

Test 3: Verbal Attention. This short-term working memory test obviously taps working memory in that the examinee is required to hold the stimuli in awareness while searching for the correct answer. Some element of inhibition also is required because the examinee must sustain attention and hold off on answering until he or she discovers the correct stimuli.

Test 4: Letter-Pattern Matching. This measure of processing speed requires inhibition; disinhibition on this task could easily result in the examinee choosing an incorrect distractor.

Test 5: Phonological Processing. This seemingly simple task is actually quite complex in regard to the multitude of assessed abilities, including auditory processing, phonetic coding, semantic memory, language development, speed of lexical access, and word fluency (Schrank et al., 2016). This test is comprised of three separate tasks that may have differential EF involvement. The simplest task, Word Access, requires the examinee to generate words based upon a phonemic cue. This task should be differentiated from a traditional phonemic fluency task, such as an FAS task, (typically considered an EF task), because, in this case, the participant does not need to generate multiple words with the same initial phonemic cue. The second task, Word Fluency, is a phonemic fluency task that is more related to EF (Alvarez & Emory, 2006; Baldo, Shimamura, Delis, Kramer, & Kaplan, 2001) in that it requires cognitive flexibility. The third task, Substitution, requires phonemic substitution and is less of an EF measure.

Test 6: Story Recall. Story Recall requires specific memory allocation and short-term maintenance of the information in order to recall it exactly. Thus, this test taps EF via the updating component of auditory working memory.

Test 7: Visualization. This test requires the mental manipulation of visual stimuli and taps visual working memory.

Test 8: General Information. Although minimal executive functions are required to complete this task, as is the case with Test 1: Oral Vocabulary, deficits in EF throughout the examinee's lifespan may have interfered with his or her ability to acquire knowledge.

Test 9: Concept Formation. This fluid reasoning task assesses verbal inductive reasoning. It requires working memory to hold information and goals in mind until rules are formed and mental flexibility to change rules.

Test 10: Numbers Reversed. This test assesses auditory working memory.

Test 11: Number-Pattern Matching. There is a mild inhibition component to this measure of processing and perceptual speed, given the need to resist distractors.

Test 12: Nonword Repetition. Although there is some need to utilize components of working memory for this task, the theoretical load of this construct would be minimal.

Test 13: Visual-Auditory Learning. The associative learning component of this test requires some working memory abilities.

Test 14: Picture Recognition. Although an argument could be made that this test requires working memory, it is primarily designed to measure visual-spatial processing and visual memory. Inhibition is required in that the examinee must resist distractors.

Test 15: Analysis-Synthesis. The deductive reasoning component of this fluid reasoning task requires cognitive flexibility.

Test 16: Object-Number Sequencing. This is the most complex of the working memory tasks on the WJ IV COG (Schrank et al., 2014b). It also requires, to an extent, cognitive flexibility to simultaneously order stimuli.

Test 17: Pair Cancellation. This test has a mild inhibition component because the examinee must resist distractors.

Test 18: Memory for Words. This test can provide information about verbal immediate memory span and attention, and it requires some components of working memory. However, examinees do not need to manipulate information held in awareness, which keeps the working memory component at a moderate level.

Discussion

The purpose of this Assessment Service Bulletin (ASB) was to provide a brief review of EF constructs and to provide a guide for researchers and clinicians regarding WJ IV tests that may assess components of EF. This ASB focused on only the WJ IV COG. EF likely also impacts performance on specific measures of the *Woodcock-Johnson IV Tests of Oral Language* (Schrank, Mather, & McGrew, 2014b), as well as academic skills, as measured by the *Woodcock-Johnson IV Tests of Achievement* (Schrank, Mather, & McGrew, 2014a). Further reviews are needed to provide meaningful interpretation of EF on constructs measured in the WJ IV COG and in these other batteries.

Because there is disagreement in the literature concerning the construct definition of EF and the specific cognitive components measured by EF tests, a review of research on EF measurement was included to justify several assumptions used in this review. This ASB focused on EF components involving inhibition, working memory, and cognitive flexibility. Additionally, task demands from individual WJ IV COG tests were reviewed to determine the extent to which tests involved these individual EF constructs. Qualitative reviews from different theoretical perspectives or different operational definitions of EF would likely result in different conclusions and assertions than those made in the current ASB, and empirical validation studies are needed in this area.

Despite these limitations, it is highly likely that tests of the WJ IV COG have differential EF demands. Not surprisingly, given that working memory is a key component of CHC theory and is one of the measures that the WJ IV was designed to assess, the most prominent EF construct on this measure is WM. It is important to reiterate that there is some debate about whether WM is an executive function itself or is a necessary component of other abilities that are considered measures of EF. Given that WM constructs are highly correlated with EF and fluid reasoning (FR) measures, EF deficits most likely would manifest as low scores on WJ IV COG measures that involve WM, which include most FR measures.

Several tasks of the WJ IV COG involve cognitive flexibility, which was operationalized in the current review based on the degree of changing task demands and the requirement of flexibly shifting attention in novel problem solving. Deficits in cognitive flexibility would likely lower overall scores on several of the WJ IV COG measures (see Table 2). However, cognitive flexibility is not explicitly measured by WJ IV COG tests and is primarily involved in tasks with changing performance demands. Qualitative analysis of how an examinee's performance may be impacted by changes in test instructions is important for detecting cognitive flexibility deficits in the WJ IV. In general, inhibition deficits would likely manifest as slowed information processing speed due to distractions during timed tests or impulsive responding. Severe inhibition deficits may result in quick responses on any forced choice task, which would likely be obvious via qualitative observation. Because poor performance on a test measuring working memory may be secondary to inhibition deficits, performance on WM tests also may be impacted by inhibition deficits.

Given the potential influence of EF on a wide array of volitional behaviors, EF likely impacts all cognitive tests to some degree. However, the degree and the type of effect varies based on the specific task demands. Clinical observation is also an important component of detecting EF deficits, especially when using measures that do not explicitly measure EF components. EF deficits may most likely manifest in the WJ IV on measures with high working memory demands. Clinicians should be aware that EF deficits may be one of many likely reasons for a pattern of low scores on tests identified in this review as having EF involvement. Additionally, as discussed above, EF deficits can contribute to neurodevelopmental delays that affect the acquisition and learning of information, and therefore, would be expressed on a test tapping crystalized knowledge. In these situations, performance on the test may not require EF, although the EF deficit can still have an impact. Low scores, even on tests identified as measuring EF, may not provide sufficient information for identifying the underlying EF component. For example, EF deficits may result in a pattern of low scores on specific measures of FR (e.g., Test 9: Concept Formation, Test 15: Analysis-Synthesis). However, additional measures would need to be administered to determine whether the pattern of low scores is due to inhibition, WM, cognitive flexibility deficits, or another ability considered under the EF umbrella. In addition to analyzing measures of EF, clinicians should corroborate test-taking behavior with patterns of performance. For example, looking at observed impulsive responding, difficulty remaining seated, and short attention span during test administration may help differentiate the involvement of impulsivity from other EF components in contributing to test performance.

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Appendix

Woodcock-Johnson IV Tests of Cognitive Abilities: Test Descriptions and Associated CHC Factors and Ability Clusters

Test	Description	CHC Factors/Ability Clusters
Test 1: Oral Vocabulary	Requires the examinee to provide synonyms and antonyms to words	Comprehension-Knowledge (*Gc*)/Vocabulary
Test 2: Number Series	Requires the examinee to complete a numerical pattern	Fluid Reasoning (*Gf*)/Quantitative Reasoning
Test 3: Verbal Attention	Requires the examinee to repeat specific auditory stimuli (numbers, animals)	Short-Term Working Memory (*Gwm*)/Cognitive Efficiency
Test 4: Letter-Pattern Matching	Requires the examinee to identify identical letter combinations within a collection	Cognitive Processing Speed (*Gs*)/Perceptual Speed, Cognitive Efficiency
Test 5: Phonological Processing	Requires the examinee to provide words with certain phonological criteria or to alter the phonology within a word	Auditory Processing (*Ga*)
Test 6: Story Recall	Requires the examinee to repeat a story	Long-Term Retrieval (*Glr*)
Test 7: Visualization	Requires the examinee to select pieces to complete a puzzle	Visual Processing (*Gv*)
Test 8: General Information	Requires the examinee to provide the description of an object's location or purpose	Comprehension-Knowledge (*Gc*)
Test 9: Concept Formation	Requires the examinee to identify the underlying rule or pattern	Fluid Reasoning (*Gf*)
Test 10: Numbers Reversed	Requires the examine to repeat a collection of numbers in reverse order	Short-Term Working Memory (*Gwm*)/Number Facility, Cognitive Efficiency
Test 11: Number-Pattern Matching	Requires the examinee to identify identical numbers in a row as quickly as possible	Number Facility, Perceptual Speed, Cognitive Efficiency
Test 12: Nonword Repetition	Requires the examinee to repeat imaginary words	Auditory Processing (*Ga*)
Test 13: Visual-Auditory Learning	Requires the examinee to study and later recall symbols with ascribed meanings	Long-Term Retrieval (*Glr*)
Test 14: Picture Recognition	Requires the examinee to recollect previously viewed images	Visual Processing (*Gv*)
Test 15: Analysis-Synthesis	Requires the examinee to solve a visual puzzle based on a given key	Fluid Reasoning (*Gf*)/Quantitative Reasoning
Test 16: Object-Number Sequencing	Requires the examinee to repeat specific auditory stimuli (numbers, objects)	Short-Term Working Memory (*Gwm*)
Test 17: Pair Cancellation	Requires the examinee to identify a specific pattern among randomized images	Cognitive Processing Speed (*Gs*)
Test 18: Memory for Words	Requires the examinee to repeat multiple words in the same order	Auditory Memory Span

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