Executive Function and Ambiguous Sentence Comprehension

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Purpose: Sentence comprehension is a critical skill in today’s literate society. Recent evidence suggests that processing and comprehending language taps cognitive as well as linguistic abilities, finding that has critical import for clinicians who have clients with language disorders. To promote awareness of the impact of cognition, especially executive function (EF) and working memory (WM), this opinion article presents current views of how sentences are processed and links the various steps of the process to specific EF and WM subcomponents.

Method: The article focuses on ambiguous sentences, pointing out the similar types of processing needed when resolving an ambiguity and performing EF tasks.

Results: We discuss the potential overlap between the neurobiology of sentence processing and EF and the evidence supporting a link between EF and sentence processes.

Conclusion: Awareness of the potential role of EF and WM in sentence comprehension will help clinicians be more aware of potential cognitive-linguistic deficits in their clients. Future research will help to clarify the link between EF and sentence comprehension.

Sentence comprehension is a necessary skill for successful communication. Individuals with difficulty processing and comprehending sentences will be disadvantaged socially, academically, and vocationally. Sentence comprehension is supported in part by cognitive processes, such as executive functioning (EF) and working memory (WM). Concomitant deficits in complex cognition, including EF and WM, and sentence comprehension exist in several populations with impairments, such as in adults and children with Down syndrome (e.g., Chapman, 1997; Chapman, Schwartz, & Bird, 1991; Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010; Rowe, Lavender, & Turk, 2006), adults and children with a history of traumatic brain injury (TBI; e.g., Brooks, Bos, Greve, & Hammond, 1999; Butler-Hinz, Caplan, & Waters, 1990; Coelho, Liles, & Duffy, 1995; Hincliffe, Murdoch, & Chenery, 1998; Kennedy et al., 2008), adults with aphasia (e.g., Martin, 2006; Murray, 2012), adults with Parkinson’s disease (e.g., Grossman, Lee, Morris, Stern, & Hurtig, 2002; Kehagia, Barker, & Robbins, 2013), children with autism (e.g., Hill, 2004), children with attention-deficit/hyperactivity disorder (ADHD; e.g., Nigg, Blaskey, Huang-Pollock, & Rappley, 2002), and children with specific-language impairment (e.g., Henry, Messer, & Nash, 2012; Im-Bolter, Johnson, & Pascual-Leone, 2006; Montgomery, 2000). It is not always clear whether or how the cognitive and communication impairments are related in these groups, and any relationship is likely to be multifactorial. Understanding the link between cognitive and linguistic processing may help the clinician to identify potential problem areas and may suggest ways to address these impairments in individuals with complex profiles. This examination of the literature on EF provides specific information about how sentence comprehension occurs and how EF may support sentence comprehension. The goal of this article is to provide an introduction to sentence processing and comprehension and an overview of the potential interactions between sentence processing and EF, which will be useful to both clinicians and researchers as new research in this area continues to emerge.

The relationships between sentence comprehension and cognitive abilities, in particular EF and WM, are especially relevant to clinicians working with clients who have cognitive impairments, such as individuals with a history of TBI or ADHD and also those who have sentence comprehension impairments. However, although the relationship between WM and individual variability in sentence comprehension performance has been well explored (e.g., Just & Carpenter, 1992; Kemper & Sumner, 2001; MacDonald & Christiansen, 2002; Waters & Caplan, 1996; Wiseheart, Altmann, Park, & Lombardino, 2009), studies examining
the contribution of EF to sentence comprehension have been sporadic until fairly recently (Fedorenko, 2014; Grossman et al., 2002; January, Trueswell, & Thompson-Schill, 2009; Lieberman et al., 1992; Novais-Santos et al., 2007; Novick, January, Trueswell, & Thompson-Schill, 2004; Novick, Trueswell, & Thompson-Schill, 2005; Ye & Zhou, 2009). Individual differences in EF, which has been defined as a collection of intentional or voluntarily controlled cognitive processes (Alvarez & Emory, 2006; Jurado & Rosselli, 2007; Lezak, 1982; Miyake et al., 2000; Stuss & Alexander, 2000), may explain a large portion of clinically relevant individual variability in sentence comprehension performance. It is important to note that EF is not a unitary construct (Alvarez & Emory, 2006; Miyake et al., 2000; Stuss & Alexander, 2000). Therefore, the hypotheses that drive this article are first, that a variety of cognitive functions are used during sentence processing and comprehension. Next, the type of cognitive function used can be inferred based on an analysis of the task demands of different steps during sentence processing and comprehension. Thus, it is necessary to analyze subcomponents of EF and how they may relate to the processing and comprehension of complex sentences in order to make predictions for future research.

This review initially provides a summary of the potential overlap between the neurobiology of sentence processing and EF, which provides information relevant to clinicians and theoretical context and motivation for the rest of this discussion. Then, we provide an overview of sentence comprehension, EF, and WM, followed by a step-by-step description of how EF may affect sentence comprehension processes. We also discuss assessment of sentence comprehension and EF and highlight disorders that frequently exhibit impairments of the different processes under discussion. Finally, we provide some concrete suggestions for future research in our conclusions. It is also important to note what is beyond the scope of this particular article. Given that understanding the relationship between EF and sentence processing represents a wide-ranging, interdisciplinary effort, this article cannot provide a complete review of all the specific areas of research we touch upon, such as sentence processing, EF, WM, and the neural foundations of these. Although we provide examples of clinical categories in which sentence comprehension or EF has been studied, the goal of the article is not to survey the wide literature of these various etiologies. Instead, we aim to provide enough of an overview of the relevant areas to support a discussion of how the overlap might affect clinical populations and decisions about treatment. We also provide references of reviews and resources for more in-depth information about many of the areas we discuss.

Neurological Correlates of Sentence Comprehension and EF

One of the motivations for exploring overlap between sentence comprehension and EF is that neuroimaging studies have identified cortical regions that are apparently active during both cognitive and language tasks. One of the regions that has been the topic of much cognitive research is Broca’s area, which is, of course, traditionally considered a language area. However, it is also active in a wide variety of commonly used EF tasks that vary in the degree of cognitive control required and do not necessarily involve verbal processing (Novick, Trueswell, & Thompson-Schill, 2010). Broca’s area comprises Brodmann Area (BA) 44 (pars opercularis) and BA 45 (pars triangularis) in the left hemisphere. In sentence processing, BA 44 and 45 are argued to support somewhat separable functions (Fedorenko, Nieto-Castañón, & Kanwisher, 2012; Fedorenko & Thompson-Schill, 2014; Friederici, 2011, 2012). BA 45 is argued to support semantic processing, along with the middle and posterior superior temporal gyrus, medial temporal gyrus, and BA 47 (pars orbitalis, anterior to Broca’s area). BA 44 is argued to support syntactic processing, along with the posterior superior temporal gyrus. BA 44 and 45 have been shown to have overlapping activation when sentences require unusual mapping of semantic and syntactic information, as in noncanonical sentences such as passives (for reviews, see Fedorenko et al., 2012; Fedorenko & Thompson-Schill, 2014; Friederici, 2011, 2012).

In neuroimaging studies of EF, BA 44 and 45 are both active during a variety of EF functions (Collette, Hogge, Salmon, & Van der Linden, 2006; Koechlin & Jubault, 2006; Koechlin, Ody, & Kouniher, 2003; Miller & Cohen, 2001): updating of WM (see Collette et al., 2006), cognitive control (e.g., Novick et al., 2010), and hierarchical control of behavior (Koechlin & Jubault, 2006). Novick et al. (2010) have argued that Broca’s area subserves cognitive control, which they define as overriding a conflict or overriding an expected stimulus. This resolution of a conflict is also a necessary component of language processing, as illustrated by Novick et al. and Thothathiri, Kim, Trueswell, & Thompson-Schill (2012), who have explored it using behavioral and neuroimaging methods. Providing an alternate perspective, Koechlin and Jubault (2006) have proposed that Broca’s area is involved with hierarchical control of behavior. They define cognitive control as the ability to coordinate thoughts or actions in accordance with internal goals (Koechlin et al., 2003). In particular, Koechlin and Jubault provide evidence that BA 44 is involved with simple sequences of discrete actions, whereas BA 45 is involved with sequencing superordinate groups of the simpler action sequences. This has obvious implications for language processing, which also requires hierarchical processing. These findings, in tandem with copious evidence that Broca’s area is critical for language use (Murray & Clark, 2006; cf. Dronkers, Wilkins, Van Valin, Redfearn, & Jaeger, 2004), converge on the possibility that both language and cognitive processing utilize neural resources in Broca’s area; however, evidence to date is circumstantial. Several research groups have highlighted the need for future neuroimaging research to explore cognitive and language tasks in the same individuals (Fedorenko & Thompson-Schill, 2014; Novick et al., 2010). Emerging studies addressing this issue are discussed in the next paragraphs.
In the past, the neural systems supporting EF have been assumed to be located in the prefrontal cortex (Miller & Cohen, 2001). However, current research has found that there are many regions contributing to EFs located bilaterally, including Broca’s area as discussed previously, the prefrontal cortex, the anterior cingulate cortex, the parietal lobe, and subcortical structures (e.g., Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; Collette et al., 2006; Fontaine, Azouvi, Remy, Bussel, & Samson, 1999; Lezak, 1982; Merkley, Larson, Bigler, Good, & Perlstein, 2013; Pardo, Pardo, Janer, & Raichle, 1990; Stocco, Lebiere, O’Reilly, & Anderson, 2012; Yin et al., 2012). A complete review of the extensive literature on the neural systems that support EF is beyond the scope of this article, but we invite the reader to review the articles mentioned in this paragraph, in particular Collette et al. (2006), Miller and Cohen (2001), and Koechlin et al. (2003). The extent to which each of these other regions contribute to sentence comprehension is an open question.

The potential for neural overlap between sentence comprehension and EF is of clear clinical and theoretical importance. Sentence comprehension and EF are both complex behaviors that encompass many lower level functions, so identifying single regions, such as Broca’s area, that support both is too simplistic. Future research identifying the neural networks underlying both EF and sentence comprehension will be of great interest to clinicians and neuroscientists alike. At present, though, a more thorough understanding of sentence comprehension and EF is more attainable.

Sentence Comprehension and Ambiguous Sentences

Sentences in isolation provide a controlled environment to test how cognitive abilities relate to within-sentence processing and comprehension. A crucial characteristic of sentence processing and comprehension, whether the sentence is oral or written, is that both necessarily unfold over time, incrementally. Completely processing a sentence does not automatically entail successful comprehension. It is possible that a sentence may be fully processed but comprehended incorrectly. For example, when reading the sentence “While the woman bathed the baby spat up on the bed,” participants in a study by Christianson, Hollingworth, Halliwell, and Ferreira (2001) accurately responded to questions about whether the baby spat up on the bed (it did) but were less accurate on questions about whether the woman bathed the baby (she did not).

Sentences with syntactic ambiguities have proven difficult even for people with no disorder. These are sentences in which the structure of the sentence is not obvious on initial reading. Ambiguous sentences occur frequently during everyday language use, not only in academic literature and assessments. A few of our favorite, though rather extreme, examples, called “crash blossoms,” have been collected from newspaper headlines: “Gator Attacks Puzzle Experts” or “Squad Helps Dog Bite Victim” (see Zimmer, 2010, for more examples). In real-world contexts, ambiguities are typically resolved easily and often go unnoticed. For example, it is less plausible that alligators were attacking “puzzle experts” than that attacks by alligators were puzzling. Similarly, when accompanying a picture of a person with a dog bite, the headline, “Squad Helps Dog Bite Victim” is not difficult to interpret. However, nearly any impairment of language or cognitive processing may make confusions over ambiguity interpretation more frequent or more difficult to resolve.

Theoretical models of sentence processing agree that processing is primarily incremental, with the structure of the sentence being updated as each new word is encountered (Frazier & Rayner, 1982; Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Kimball, 1973; MacDonald, Pearlmutter, & Seidenberg, 1994). Thus, the structure may occasionally require reanalysis in a syntactically ambiguous sentence when an incongruity is perceived. For example, for the sentence “The waitress served soup during her lunch break tried not to burn her tongue,” the typical initial interpretation is that the waitress was serving soup, that is [[The waitress][served soup during her lunch break]] (Frazier & Rayner, 1982; Kimball, 1973; Rayner, Carlson, & Frazier, 1983; Rayner & Frazier, 1987). However, when the verb tried is encountered, the sentence must be reanalyzed to resolve the ambiguity, leading to only one possible interpretation: [The waitress [served soup during her lunch break] tried not to burn her tongue]. Thus, a second stage of processing would be necessary to correctly parse “served soup...” as a reduced relative clause. This two-stage model of parsing illustrates the critical importance of WM for successful comprehension, due to the necessity of recalling the exact sentence for the second, reinterpretation phase.

Research has shown that adults with no disorders take into account a variety of information during sentence processing, such as the frequency with which a verb occurs with direct objects or embedded clauses (Garnsey et al., 1997), the frequency with which a verb occurs in transitive or intransitive sentences (Garnsey et al., 1997), plausibility (Christianson, Luke, & Ferreira, 2010), and even visual or referential context (G. T. M. Allmam, 1998). As a relevant aside, children may not take these constraints into account, which may relate to the development of EF (Mazuka, Jincho, & Oishi, 2009; Trueswell, Sekerina, Hill, & Logrip, 1999; Weighall, 2008). Because constraint-based models maintain that a large number of variables may affect sentence processing, this suggests that there is a need for EF resources to manage and evaluate the various constraints that might apply in a given sentence (Novick et al., 2005).

Executive Function and Working Memory

EF roughly refers to the ability to control and regulate one’s thought processes. The concept of EF has long been criticized as being overly vague or at least difficult to define (Burgess, 1997; Strauss, Sherman, & Spreen, 2006). EF has been sometimes considered to be synonymous, or at
least closely related to, at least two other constructs: supervisory attention/attentional control (Collette & Van der Linden, 2002; McCabe, Rodiger, McDaniel, Balota, & Hambrick, 2010; Miyake et al., 2000) and the unitary g factor of general intelligence (Duncan, Burgess, & Emshie, 1995). EF is now widely defined as a collection of intentional or voluntarily controlled, higher order processes that have both shared and discrete aspects involved in supervising and controlling lower order cognitive processes (Alvarez & Emory, 2006; Jurado & Rosselli, 2007; Lezak, 1982; Miyake et al., 2000; Stuss & Alexander, 2000). These higher order EF processes require effortful control of cognitive processing and include voluntary planning, problem solving, goal selection, cognitive flexibility, inhibition of inappropriate actions, and many others (Fernandez-Duque & Posner, 2001; Spreen & Strauss, 1998). The lower level functions that are controlled or supervised by EF include different subtypes of attention and memory (Fernandez-Duque & Posner, 2001). In fact, neuropsychologists consider WM to be an EF subprocess. Furthermore, some researchers consider EFs to be only, or especially, necessary in situations that are novel or require adaptation (Miike et al., 2000; Stuss & Alexander, 2000).

EF impairments can significantly affect successful performance in work or school and may entirely prevent reaching educational and career goals. In populations with primary EF impairments, how these contribute to sentence comprehension deficits and how the interaction of these two then interact with disability is not well understood and could account for some difficulties with employment and education. These deficits and their treatment are within the scope of practice of speech-language pathologists (SLPs; American Speech-Language-Hearing Association [ASHA], 2003, 2005); therefore, clinicians need to be aware of these issues and the evolving understanding of the relationship between EF and language. SLPs who work with adults or children with cognitive impairments should consider an assessment of EF to be critical for planning treatment because many individuals with cognitive deficits have comorbid language impairments (e.g., TBI, ADHD, autism; Brooks et al., 1999; Hill, 2004; Nigg et al., 2002). Whereas neuropsychologists typically assess EF, SLPs may be involved in screening for, identifying, assessing, or treating EF impairments, depending on each individual’s level of training and particular roles and responsibilities in the workplace (ASHA, 2003, 2005). In settings where neuropsychologists or other professionals assess EF during their evaluations, being able to interpret the findings of these assessments is highly relevant and important to the SLP. It is also important to coordinate evaluation to avoid overlap of test selection because SLPs and neuropsychologists use some of the same tests. ASHA (2003) has a helpful discussion of the particular roles of SLPs and neuropsychologists for reference. With these factors in mind, we discuss a subset of the many EF processes found in the literature that we believe are the most essential for language processing and comprehension: planning, self-monitoring, conflict resolution, shifting, updating of memory, and inhibition. Subsequently, we discuss the complex relationship between EF and WM.

Planning and Self-Monitoring

The EF constructs of planning and self-monitoring are two of the original EF processes identified by Muriel Lezak (1982) in her seminal work. Planning refers to the ability to anticipate and adapt to future needs. Abilities such as detecting patterns from previous experience and deviations from expected patterns are crucial to planning, as are abilities such as problem solving and making decisions. In addition, being able to generate alternative strategies when events deviate from expected patterns is a crucial skill for planning. Planning skills are impaired in many populations with EF impairments, especially TBI, dementias, and ADHD (Strauss et al., 2006). With respect to sentence processing and comprehension, planning skills would be essential for establishing a goal to comprehend a sentence and then updating that goal to expend additional effort when encountering a particularly complex or ambiguous sentence (Collette & Van der Linden, 2002).

Self-monitoring is an EF that requires regulation of attention, often in a dual-task situation (e.g., monitoring your speech while you are talking) as well as a strong degree of metacognition to compare current behaviors with expected behaviors. For example, when listening to a lecture, you must monitor your understanding of the material so that you can clarify any incongruities in your understanding by asking questions. Deficits in monitoring can be observed informally during many complex tasks (Lezak, 1982; Salthouse, Atkinson, & Berish, 2003) and again may characterize some behaviors by those with acquired brain injuries from TBI, for example. Verbal and design fluency tasks or a complex task with rules such as the Tower of Hanoi test (Simon, 1975) can be used to observe what happens when a rule is violated. For example, deficits in monitoring can manifest as failure to notice errors, repeating words or designs in fluency tasks, or changing rules inappropriately in the middle of the task. On a pragmatic level, impaired self-monitoring of the appropriateness of behavior is a hallmark of TBI (Sohlberg & Mateer, 2001), behavioral variant primary progressive aphasia (Reilly, Rodriguez, Lamy, & Neils-Strunjas, 2010), and mid- to late-stage Alzheimer’s disease (Hart et al., 2003). Conflict resolution is one important ability that would be activated subsequent to successful monitoring. When monitoring identifies a conflict or error, conflict resolution then allocates resources to shifting or inhibition abilities in order to successfully resolve the error (Luo, Niki, & Phillips, 2004).

Shifting, Updating Memory, and Inhibition

Shifting, updating of memory, and inhibition have been identified as crucial EF components used in conflict resolution processes and are highlighted in the widely cited study by Miyake et al. (2000). They used tasks that they
argued isolated these discrete EF subprocesses and also administered more complex tasks such as the Wisconsin Card Sorting Test and the Tower of Hanoi test that tap multiple subprocesses. Miyake et al. found that the discrete tasks used explain a large proportion of the overlap and separation of abilities needed in the Wisconsin Card Sorting Test and Tower of Hanoi test. More recent work by Miyake and Friedman (2012) has refined their model to include a “common EF” ability. They reported that this common EF factor correlates perfectly with inhibition scores, suggesting that inhibition scores provide a good estimate of “common EF.” Therefore, we will continue to refer to inhibitory ability as one of the EF subprocesses essential to sentence processing. It is interesting that the neuromaging evidence reviewed by Collette et al. (2006) supports the findings of Miyake et al. that EF tasks have both shared and separable components.

Shifting, updating, and inhibition are not the only EF abilities, but they help to describe the cognitive demands of more complex EF tasks in Miyake et al. (2000) and Miyake and Friedman (2012) and, we believe, are essential for everyday language processing and comprehension. Updating one’s understanding of the current discourse must happen continually and in real time as the message unfolds. Inhibition is required to filter out competing meanings of words, whereas shifting is required to shift between alternative sentence parses. Conflict resolution is required to control lower level processing when conflicting information is noticed during the monitoring of the meaning of the current discourse. During conflict resolution, the focus of processing must be broadened to reanalyze and integrate all conflicting information (for a discussion of how this detection occurs, see Botvinick et al., 2001, 2004). This reanalysis would then require updating one’s comprehension of the ongoing discourse and inhibition of the previous interpretation.

The collection of cognitive subcomponents that EF comprises and the tasks used to measure them are, unfortunately, not universally agreed upon or defined (Jurado & Rosselli, 2007; Lezak, 2004; Strauss et al., 2006; Stuss & Alexander, 2000). Motivation, for example, is considered to be an EF by Lezak (1982) but not by Alvarez and Emory (2006). Most of the EF subcomponents are themselves umbrella terms that encompass more specific abilities, as is common with many complex behaviors. Figure 1 illustrates the way many of the EF subcomponents found in the literature relate to one another. It organizes the terms by their definitions under the overarching clinical framework provided by Lezak (1982; Lezak, Howieson, Bigler, & Tranel, 2012): volition, planning/decision making, purposive action, and effective performance. The three fundamental EFs that Miyake et al. (2000) posited all fall under the heading of “Completing purposive actions” and are included in the figure, with inhibition and set-shifting in one category and updating in a separate category. The overarching framework is useful for understanding when a specific process may be utilized in a functional context as well for interpreting the various terms for similar EF subprocesses that may be found in the literature.

**Working Memory and Executive Function**

WM has a complex relationship with EF and is included in the diagram of EF subtypes in Figure 1, although it may be a separate (Lehto, 1996) or an overlapping resource (e.g., Baddeley, 1986, 2010). Baddeley (1986, 1996, 2003, 2010) developed the notion of WM in order to link the variety of concepts that had been used to describe different memory abilities, including modality-specific short-term storage of stimuli, processing of stimuli in short-term storage, control of stimulus processing, and long-term storage. In the Baddeley model of WM, modality-specific short-term storage systems, the phonological loop and the visuospatial sketchpad, maintain information in an active state, but when any manipulation of the information is required, the central executive manages processing. The central executive is also responsible for consciously directing the attention or the short-term storage systems to external events or to internal thoughts and ideas. A key characteristic of both the short-term storage systems and the central executive is that they have limited capacity: At any given time, only a limited amount of information can be held in the phonological loop or visuospatial sketchpad or manipulated by the central executive.

The central executive is the control component in WM, and different researchers have identified different abilities that may be attributed to the central executive, including information updating (Miyake et al., 2000), inhibition of irrelevant information (Engle, Kane, & Tuholski, 1999; Zacks & Hasher, 1994), and executive attention (McCabe et al., 2010). Note that all of these are abilities discussed herein as subprocesses of EF. Engle, Kane, and colleagues (e.g., Broadway & Engle, 2010; Conway, Kane, & Engle, 2003; Engle, 2002; Engle et al., 1999; Heitz et al., 2006; Kane & Engle, 2002) have extensively examined the relationship between WM capacity and executive attention. They define executive attention as the portion of WM that regulates what is currently active in memory. They have measured WM capacity using several tasks that require the storage of information while simultaneously performing a separate mental activity (Conway et al., 2005). Their measures of WM also predict performance on EF tasks, such as Stroop tasks (Kane & Engle, 2003). Overall, Engle and colleagues argue strongly that WM and EF are separate but highly related resources. The tasks used to test WM and EF may tap a shared resource (McCabe et al., 2010).

A much larger number of studies have assessed the contribution of WM to sentence processing and comprehension than have tested the contribution of EF to sentence processing and comprehension. The impact of WM on sentence processing is intuitively acceptable because the meaning and structure of the sentence must be constructed and maintained over time, and indeed there is much evidence to support this link (e.g., Baddeley, 2003; Farmer, Miyak, & Christiansen, 2012; Klemper, Almor, Tyler, Andersen, & MacDonald, 1998; MacDonald & Christiansen, 2002; Small, Kemper, & Lyons, 2000; Swets, Desmet, Hambrick, & Ferreira, 2007). Through the use of embedded clauses...
Figure 1. Terms for executive function abilities found in research and clinical models.

**VOLITION**
- Internally or externally generated goals
- Requires at least intention, motivation, and self-awareness

**PLANNING**
- Sustained attention
- Not necessarily a component but required for successful planning
- Hypothesizing and hypothesis testing
- Generate Alternatives or verbal design fluency
- Problem solving
- Decision making
- Rule detection
- Strategizing
- Conceptual Framework

**PURPOSIVE ACTION**
- Example: Carry out activities

**UPDATE**
- Working Memory
- Not considered by most to be an EF component but required for updating
- Modify or update information or internal representation
- Sequencing
- Manipulate information
- Monitoring of information

**SHIFTING & INHIBITION**
- Terms Referring to Shifting
  - Selectively attend to one and inhibit effect of other stimuli
  - Engage/Disengage appropriately
  - New operation despite negative priming and interference
  - Mental flexibility
  - Cognitive flexibility
  - Cognitive control
  - Inhibitory control
  - Attentional control
  - Attention shifting
  - Set shifting
  - Swtiching

- Types of Inhibition
  - Motor response Inhibition
  - Cognitive inhibition
  - Suppressed irrelevant information already in working memory
  - Resistance to Interference
  - Prevents irrelevant information from entering working memory
  - Unintentional Inhibition
  - Can lead to reactive inhibition
  - Inhibition of prepotent response
  - Current target requires a no response but it required ‘yes’ recently
  - Intentional Inhibition
  - Inhibition of Return (IOR)
  - Target in a location that was previously cued; IOR occurs after a brief period of enhancement with the initial cue
  - Negative Priming
  - Current target where a distractor used to be

**DUAL TASK or TIME SHARING**
- Allocate resources between tasks or processes

**CONFICT RESOLUTION**
- Shifting when monitoring identifies an internal representation not compatible with current demands

**EFFECTIVE PERFORMANCE**
- Example: Monitor, self-correct, regulate tempo and intensity
- Effective performance is required throughout many of the above processes

The overarching framework of volition, purposive action, and effective performance refers to the clinical framework posited by Lezak et al. (2012) and helps to organize the many terms found in the literature. Specific constructs explored by Miyake et al. (2000) are in the Purposive Action: Shifting, Inhibition, and Updating. Our discussion primarily focuses on WM, monitoring, conflict resolution, inhibition, and set shifting. Many named abilities may overlap or synonymous, and some terms are left out for the sake of space.

Lezak, 1982, 2004, 2012; Stuss & Alexander, 2000; Spreen & Strauss, 1998; Salthouse et al., 2003; Alvarez & Emory, 2006; Lehto, 1986; Grossman et al., 2002; Miyake et al., 2000; Carpenter, Just, & Reiche, 2000; Jarama & Rossi, 2007. Some consider inhibition to be a possible underlying feature of all EF subcomponents (Miyake et al., 2000); the types listed are not necessarily mutually exclusive. Hamish, 1995; Wilson & Kipp, 1998; Jonides, Smith, Maruzeit, Koepepe, & Reuter-Lorenz, 1995; Collette & Van der Linden, 2002; Mazuka, Jinho, & Oishi, 2009; Novick et al., 2005; Cowan, Fristoe, Elliott, Brunner, & Saults, 2006; Baddeley, 1996. Flexibility is often used more loosely to refer to shifting, switching or even the take many viewpoints especially in novel contexts. Spreen and Strauss (1998) separate cognitive flexibility into spontaneous flexibility, synonymous with fluency, and reactive flexibility, defined as shifting. Klein, 2000. Note the absence of emotional regulation, which has been described as an integral subcomponent of EF by some (Lezak, 1982; Stuss & Alexander, 2000).
and phrases, sentences can be arbitrarily long and can contain quite a bit of information that must be integrated into a single meaning. For this reason, research on WM and sentence processing proceeded research on EF and sentence processing by decades. Even when there is controversy over the best WM measures for predicting sentence comprehension, there is still general agreement that WM can limit sentence processing. However, debate continues regarding whether the WM used for sentence comprehension is specific to the language domain (Caplan & Waters, 1999) or more domain general (e.g., Kane and Engle, 2002). It is beyond the scope of this article to provide a full review of the importance of WM to sentence processing and sentence comprehension, but see Caplan and Waters (1999, 2013), Just and Carpenter (1992), and Martin (2006) for further information.

In the speech pathology literature, it has been shown that adolescents with a history of brain injury perform worse on language tasks with higher memory requirements (Moran & Gillon, 2004; Turkstra & Holland, 1998) and that minimizing those memory requirements may improve performance on standardized measures (Turkstra & Holland, 1998). In a similar fashion, older adults with impaired WM or dementia also have difficulties with sentence comprehension related to WM impairments (Kempler et al., 1998; Small et al., 2000). This highlights one of the reasons it is important to understand how cognition and sentence comprehension are related, given that impairments in language comprehension could be due to either language or WM impairments. Determining how and when EF may contribute to sentence processing and comprehension is more difficult.

**Sentence Comprehension, EF, and WM: Step by Step**

A good case can be made for the involvement of EF in many different aspects of language (e.g., Martin, Yan, & Schnur, 2014; Nozari, Dell, & Schwartz, 2011; Thothathiri, Gagliardi, & Schwartz, 2012; Ye & Zhou, 2009), and the existence of a general connection between EF and language is widely accepted (e.g., Fedorenko, 2014). However, the specifics of this connection are not well understood. For example, as Fedorenko and Thompson-Schill (2014) point out, when and how EFs become involved with language processing have yet to be fully clarified. Even though it is clear that EFs are sometimes used during language comprehension, it is not clear whether this activity is necessary for language comprehension (Fedorenko, 2014). Here, we discuss one plausible outline of how EFs and sentence comprehension relate. The matter of when EFs become involved is not discussed in the same depth. However, this issue is integral to understanding the functional significance of the relationship between EFs and sentence comprehension, particularly when one and/or the other is disrupted. One likely possibility is that EFs are recruited to help with top-down processing when sentence comprehension is more challenging—for example, when sentence comprehension is happening under less than ideal conditions or when the sentence itself is unusually complex. EF may also make comprehension easier or more efficient overall (Fedorenko, 2014). This leads to the prediction that impairment of cognitive processing in one of these areas would perhaps slow down sentence processing or lead to specific types of errors in sentence comprehension.

To illustrate the importance of EF in sentence processing and comprehension, we highlight the cognitive requirements at each step of the processing of a single sentence. In particular, we focus on planning, self-monitoring, conflict resolution, shifting, updating of memory, and inhibition. Much of the available evidence regarding sentence processing and EF relies on ambiguous sentence processing specifically because ambiguous sentences elicit a misinterpretation that presumably must be inhibited and then revised. This inhibition and revision has a clear parallel to EF processes, which we will describe. Other sentence types can be used to test other cognitive processes. Ambiguous sentences provide a good test case for examining the relationship between EF and sentence processing.

This ambiguous sentence is used in the current discussion: *The waitress served soup during her lunch break tried not to burn her tongue*. In the following, sentence comprehension is broken up into three stages: (a) initial interpretation, (b) encountering the unexpected ending, and (c) revising the initial interpretation.

**Initial Interpretation: The waitress served soup during her lunch break ...**

At this stage in sentence comprehension, psycholinguistic theory suggests that the reader/listener builds an initial sentence structure to guide in interpreting the meaning of the sentence (Frazier & Rayner, 1982; Garnsey et al., 1997; MacDonald et al., 1994). As discussed in the section on overviewing sentence processing, this initial interpretation is based on word order, word meaning, and properties of the words involved (e.g., word class and, depending on the theory adopted, whether a verb is used more often in transitive or intransitive sentences, and plausibility) and would be initially preferred over alternatives. In the case of the example sentence, readers encounter *The waitress served soup during her lunch break* and expect the sentence to be either complete or completed by a conjoined phrase, for example, *The waitress served soup during her lunch break, and she was not happy about it*. The maintenance of the words while building the overall representation of the sentence as it unfolds is supported by verbal WM.

Planning would be generally involved to establish the goal of comprehension and then updating that goal as additional effort is needed (Collette & Van der Linden, 2002). Self-monitoring ability would also play a role at this level, checking for conflict between internal and external representations of information (Lezak, 1982; Salthouse et al., 2003). In the context of sentence processing, monitoring means checking how each new word fits into the
current interpretation of the sentence that has been built up until that point. Thus, monitoring ensures that the internal representation or interpretation of the sentence matches the sentence as it is heard or read and allocates resources to conflict resolution if it does not. Individuals with TBI, dementia, or ADHD may have impairments of planning (Strauss et al., 2006). This account predicts that an impairment of planning could lead to poor comprehension accuracy if there is a poor selection of strategy to read or listen more carefully to a difficult sentence, for example. Because these individuals likely have other cognitive deficits beyond planning impairments, control of those deficits or support for those deficits would also have to be taken into account. Those with TBI, the behavioral variant of primary progressive aphasia, or mild to late-stage Alzheimer’s disease may have impaired self-monitoring (Hart et al., 2003; Reilly et al., 2010; Sohlberg & Mateer, 2001). A failure of self-monitoring could lead to confident errors—that is, errors that are perhaps made quickly or a failure to slow down during difficult reading.

**Encountering the Unexpected Word:** The waitress served soup during her lunch break tried . . .

When the reader encounters the unexpected verb, tried, the self-monitoring system must detect that the initially preferred parse (i.e., that the waitress served soup) cannot be reconciled with the incoming word. This mismatch signals a conflict that must be resolved for the sentence to be understood. Conflict when parsing may be caused either by an error, as in the case of the initial parse being incorrect in the example sentence, or by there being more than one potential interpretation, as in ambiguous words (e.g., bank as in river bank or lending institution) or ambiguous sentences that remain ambiguous without other context (e.g., I saw the boy on the hill with the binoculars). Once a conflict has been identified via monitoring, the conflict resolution system is mobilized to identify the source of the conflict and reanalyze the sentence (Luo et al., 2004). It is possible that EFs are unnecessary for simple conflicts that do not rise to the level of overt awareness (see Fedorenko, 2014).

The conflict resolution system recruits other EF sub-processes to select a suitable alternative interpretation that will resolve the conflict (Luo et al., 2004). Inhibition may be mobilized for the suppression of previously activated cognitive processes or information that is already in WM (Wilson & Kipp, 1998). In the case of this sentence, the initial interpretation of the sentence, that the waitress served soup, is already in WM and must be inhibited. Subsequent to the introduction of an additional word, shifting will be mobilized to focus on the new interpretation of the sentence. General strategies for shifting between sets may work for simple or expected conflicts, whereas more specific strategies for breaking a mental impasse may be necessary for more difficult conflicts (Luo et al., 2004).

When there are sufficient WM resources, linguistic constraints and communicative contexts may partially activate several alternative parsing possibilities while the words of the sentence are processed (Garnsey et al., 1997; MacDonald et al., 1994). Therefore, rather than having a single parse that must be shifted from once disambiguating information is encountered, several alternatives may be more or less active when the error is noticed. In this model, monitoring will continuously check the goodness of fit of the parse alternatives, using inhibition to adjust relative activation levels as each new word is encountered (Ye & Zhou, 2008). When disambiguating information is encountered, the probabilities are tipped in favor of the partially activated parse that can accommodate it. Because several alternative parses are already under consideration, this considerably lowers the difficulty of switching to a different sentence interpretation.

General deficits in inhibition are evident in perseveration, a common feature of discourse in people with a history of TBI or in people with right hemisphere damage (Lezak et al., 2012; Myers, 1999; Sohlberg & Mateer, 2001; Strauss et al., 2006). When faced with an ambiguous sentence, the person with these deficits may take longer to read it or may be unable to comprehend it due to the interference from competing interpretations. Deficits in shifting or updating may limit the ability to incorporate new information and may lead one to conclude that the sentence is ungrammatical. In contrast, self-monitoring deficits would prevent the erroneous parse from being noticed, leading to a misinterpretation of the sentence.

**Revising the Initial Interpretation:** The waitress served soup during her lunch break tried not to burn her tongue.

Conflict resolution continues to be important for revising the initial interpretation of the sentence after encountering the unexpected ending of the sentence. Shifting may be a resource recruited by conflict resolution. Shifting, defined simply as changing one’s focus from one representation to another, has been traditionally thought to require inhibition of previous items followed by activation of new items (Alvarez & Emory, 2006; Collette & Van der Linden, 2002; Stuss & Alexander, 2000). The literature has identified some specific types of shifting (see Figure 1). Set shifting, which is relevant to the sentence comprehension discussion, refers specifically to when one set of rules or one interpretation is no longer appropriate and the individual must choose another. An impairment of shifting could lead to a conclusion that the example sentence is ungrammatical or the paradoxical conclusion that the waitress served soup and also tried not to burn her tongue on the soup.

**Evidence of a Link Between EF and Ambiguity Resolution**

Monitoring, conflict resolution, set shifting, and inhibition seem particularly well suited to explain ambiguity resolution because it seems to require the detection of an incongruity, suppression of an initial incorrect parse, and a
The participants did not fully inhibit the initial, incorrect parse of an ambiguous sentence, even if they have activated the correct parse. In that study, some participants correctly interpret the second clause, *The waitress tried not to burn her tongue*, but they also do not completely inhibit the initial, incorrect interpretation, answering yes to the question, “Did the waitress serve the soup?” Thus, the participants did not fully inhibit the first parse or update their representation because they continued to believe both parses are true even after the disambiguating phrase has been processed. Participants failed to selectively inhibit the initial parse of the sentence (e.g., *The waitress serving the soup*) when the new information was not compatible with it. Although they did activate the information “waitress burned her tongue,” they did not fully shift to this parse on the basis of the new information.

The link between EFs and ambiguity resolution is supported by evidence of performance relationships between relevant tasks in the same people. Most of the evidence of a link between EFs and ambiguity resolution addresses conflict resolution or general cognitive control without a specific breakdown into inhibition, shifting, or other cognitive mechanisms. It is not that they do not discuss how inhibition may be relevant, but the measures used may be only able to lead to conclusions more generally about conflict resolution and control. Ye and Zhou (2008) found that individuals with lower cognitive control ability showed different patterns of event-related potentials when processing more versus less complex sentences than individuals with higher cognitive control abilities. In a functional MRI study, January et al. (2009) found that a Stroop task and resolution of syntactic conflict activated overlapping neural areas. In a behavioral study, Vuong and Martin (2014) compared performance on verbal and nonverbal versions of the Stroop task with processing of garden-path sentences, using sentences similar to those in Christianson et al. (2001), such as the following: “While the storm broke the windows were damaged beyond any repair.” If a comma was included after “broke,” the sentence was considered unambiguous. Vuong and Martin reported that individuals who made more errors in the grammaticality judgment task also had more verbal Stroop interference errors. Moreover, they also found that the time it takes for participants to revise their interpretation of the garden-path sentence correlates with the time to resolve the verbal (but not nonverbal) Stroop. Thus, they argue that the relationship between Stroop interference and ambiguity resolution supports the notion of the involvement of EF control mechanisms in ambiguous sentence processing.

Lesion data also support a link between conflict resolution and ambiguity resolution. Novick, Kan, Trueswell, & Thompson-Schill (2009) described a case study of an individual with a focal lesion to the left inferior frontal gyrus (i.e., Broca’s area). This individual demonstrated a general impairment to conflict resolution that was examined using cognitive tasks, a picture naming task, a verbal fluency task, and a sentence processing task. This individual also performed worse than two participants with damage to the frontal lobe that spared the left inferior frontal gyrus and a group of older adults with no history of brain damage. This case was interpreted as supporting the notion that the left inferior frontal gyrus supports conflict resolution processes and that damage to this area should result in general impairments to these processes.

Other lesion data exist that link conflict resolution in cognitive tasks and in other types of language tasks, which provides a secondary level of support for the connection between conflict resolution and sentence comprehension. For example, Vuong and Martin (2011) described two cases of individuals with a lesion to the left inferior frontal gyrus and that both took longer to resolve lexical ambiguity within sentences (i.e., “He drank the port” vs. “He drank the wine”) as compared with a control patient with damage to the parietal lobe but not the left inferior frontal gyrus and a control group of older adults without brain injury. The two individuals with injury to the left inferior frontal gyrus also performed worse than the individual with parietal damage on the attentional control tasks. It is reasonable to suggest that lexical ambiguity resolution requires similar resources as sentence ambiguity resolution.

On the basis of the evidence of a link between conflict resolution and ambiguity resolution, Novick, Hussey, Teubner-Rhodes, Harbison, and Bunting (2014) explored whether training a conflict resolution task results in improved ambiguity resolution. They assessed eye movements during the part of the sentence important for resolving the ambiguity rather than tracking comprehension. They report that when people improve on a specific conflict resolution training task, they also improve specifically on reading ambiguous sentences that require conflict resolution to resolve the ambiguity. Overall, the data support a link between EFs and sentence comprehension, though the exact nature of the relationship will take time to more fully understand (see also Fedorenko, 2014).

**Clinical Implications and Predictions**

Due to the widely distributed cortical and subcortical networks supporting EFs, impairments of EF are common in many types of acquired neurogenic and developmental disorders, and there is no single deficit or neurological characteristic that unifies the various clinical groups that may be affected by EF or sentence processing. Populations with well-documented EF impairments include those with TBI of all severities (e.g., Brooks et al., 1999; Kennedy et al., 2008; Levine et al., 2011), Parkinson’s disease (e.g., Grossman et al., 2002; Kehagia et al., 2013; McKinlay, Grace, Dalrymple-Alford, & Roger, 2010), ADHD (e.g., Nigg et al., 2002), and autism (e.g., Hill, 2004). Furthermore, Murray (2012) documented attentional and EF impairments in a group of 39 individuals with aphasia due to left hemisphere stroke. Indeed, any population that has developmental or neurogenic disorders that affect the structure of neural networks that include the frontal and/or
parietal lobes may also be at risk for EF impairments. A careful assessment of the particular cognitive impairments in a clinical group or an individual can be used to make predictions about what sentence processing deficits to expect.

EF deficits and language production deficits have been shown to be related (L. J. P. Altmann & Troche, 2011; Cannizzaro & Coelho, 2013; Coelho et al., 1995; Rogalski, Altmann, Plummer-D'Amato, Behrman, & Marsiske, 2010), and Broca’s area has been implicated as a specific area that may subserve linguistic and cognitive processing, such as those specific subprocesses we have discussed (e.g., Novick et al., 2005, 2010). However, there is a need for more individual and group studies explicitly comparing EF subprocesses with sentence processing and comprehension in populations with EF impairments. Well-defined links between impairments of EF subprocesses and sentence comprehension are rare and largely limited to the aforementioned case studies (i.e., Novick et al., 2009; Vuong & Martin, 2014). A few studies have linked deficits in EF in people with reading disorders such as dyslexia to reading ability (e.g., Altemeier, Abbott, & Berninger, 2008; Smith-Spark, Fisk, Fawcett, & Nicolson, 2003), and sentence comprehension has been linked to WM deficits in adults with dyslexia (Wiseheart et al., 2009). In a similar manner, evidence linking specific language impairment to impairments in EF and other cognitive processes is increasing (Henry et al., 2012; Im-Bolter et al., 2006).

The clinical groups we mention have little overlap in their clinical presentation. For example, stroke survivors may have somewhat circumscribed lesions, whereas TBI survivors may have more diffuse brain injury. Furthermore, some of the groups, such as TBI survivors, are particularly heterogeneous. TBI survivors have hallmark deficits in many of the EF subprocesses we have discussed herein. They may serve, therefore, as a good test population for determining whether their specific profile of cognitive deficits does in fact correspond to the sentence processing and comprehension deficits predicted from the analysis of the overlap we present. For example, do those without overt language impairments but poor Stroop interference scores take correspondingly longer to read the unexpected ending of an ambiguous sentence? Does someone with specific impairments to self-monitoring have a higher likelihood of making fast but inaccurate answers to comprehension questions? Research exploring EF and sentence processing in TBI survivors is already under way (Key-DeLyria, in press). We suggest that researchers exploring sentence comprehension or EF in clinical groups begin to incorporate both types of tasks into their studies so that data on this relationship can continue to be amassed.

Our focus on ambiguous sentences is due to their unique usefulness in testing how cognition and sentence processing relate. We do not advocate for the incorporation of ambiguous sentence treatment into clinical practice because there is not enough evidence to support the functional relevance of this approach. However, training studies can give further insight into how these abilities relate. Specific training approaches have been shown to generalize to particular tasks that overlap in cognitive demands and neural resources (e.g., Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Kray, Karbach, Haenig, & Freitag, 2012). If EF and sentence processing also tap overlapping resources, as hypothesized, they would be expected to show similar shared improvement following a successful intervention targeting specific components (e.g., Hussey & Novick, 2012). The literature supporting such a link, however, is limited to the observation that individual differences in EF correlate to individual differences in ambiguity resolution and a single recent finding that targeting conflict resolution during training generalizes to sentence processing improvements in participants without history of neurological illness or injury (Novick et al., 2014). This study linking sentence processing to conflict resolution provides limited support for the possibility that EF training would lead to enough improvement in sentence comprehension to make it relevant for populations with EF impairments. However, similar generalization has not yet been observed in impaired populations. Murray, Keeton, and Karcher (2006) found that attention-process training resulted in improved attention but not in notable communication improvements in an individual with mild conduction aphasia and impairments of WM and attention. This finding highlights that training of cognition cannot be assumed to generalize to language even when the abilities have been shown to correlate. There are a number of factors that affect improvement in any area, and generalization is yet more complex. A better understanding of the underlying shared cognitive and linguistic requirements requires amassing more data linking these specific cognitive and linguistic functions in the same participants, including participants with damage to neural regions that support these functions. These observations will aid research in the area, including translational clinical research.

Conclusion

The take-home message for the clinician is to stay tuned for further developments in understanding the specific overlap between EF and complex sentence processing that will aid communication in a wide variety of people. In the meantime, given the increasing profile of EF and language in the literature and the evidence of EF and language impairments in a number of clinical populations, clinicians may want to increase their awareness of potential cognitive deficits in individuals with neurologically based linguistic deficits and vice versa. There are several populations in particular where one or the other is often not assessed. For example, survivors of TBI are often evaluated for cognitive impairments, but in the absence of overt aphasia, more subtle language impairments may be overlooked, particularly at the level of sentence comprehension. In contrast, individuals with aphasia may have careful language evaluations, but cognition may not be tested or screened.
Many standardized assessments for children and adolescents and some for adults include sentence comprehension. However, many clinical language measures for adults are often intended for people with more severe impairments (i.e., aphasia) and, thus, may not be difficult enough to identify milder sentence comprehension impairments or impairments specific to complex or ambiguous syntactic structures (e.g., Brooks et al., 1999). Mild sentence comprehension impairments can affect function in situations demanding the use of complex language, such as the workplace, medical environments, legal situations, or even just reading adult-level literature. It is unfortunate that functional communication measures, informal or standardized, that focus on conversation or reading familiar texts do not clearly identify sentence-level impairments. Assessing sentence-level impairments is important, however, because sentences support higher level language functions. There is evidence to suggest syntactic processing deficits may be present in a population such as TBI (e.g., Butler-Hinz et al., 1990; Coelho, Liles, & Duffy, 1995; Hinchliffe et al., 1998) even if such deficits may not be typical (e.g., Angeleri et al., 2008; Coelho, 2002). Selected measures that may be useful to clinicians who regularly work with adults with subtle language impairments are included in the Appendix.

When choosing tasks to assess EF, it is particularly important to understand the potential subcomponents and the lower level cognitive functions that may also be tapped. As pointed out throughout this article, assessment of EF is challenging due to its multifactorial nature and the fact that tasks utilizing EF also include additional lower level cognitive processes (Lezak, 2004; Strauss et al., 2006). Research tasks that may better isolate components that rely on computerized reaction times are not always possible to use clinically, and test–retest reliability for such tasks is problematic (Miyake et al., 2000). Many tests that have been normed on a wide range of ages, from young children to older adults, are available to the clinician. Some of the most widely used EF tests and tests with EF subtests include the Wisconsin Card Sorting Test (Berg, 1948), the Trail Making Test (Bowie & Harvey, 2006; Reitan, 1958), the Stroop test (Stroop, 1935; Golden, 1978), WM and processing speed subtests of the Wechsler Adult Intelligence Scale–IV (Wechsler, 2008), the Cognitive-Linguistic Quick Test (Helm-Estabrooks, 2001), and the Repeatable Battery for the Assessment of Neuropsychological Status (Hobson, Hall, Humphreys-Clark, Schrimscher, & O’Bryant, 2009). However, there is no definitive agreement on which tasks are best to measure various EF components, or sometimes, even which versions of these tasks are best. SLPs who specialize in populations with cognitive impairments may be interested in several widely used compendia focusing on cognitive assessment that present basic concerns around EF definitions, commentary about each of the reviewed tests, and occasionally norms for the tests (e.g., Lezak, 2004; Strauss et al., 2006). For an SLP perspective on cognitive rehabilitation, see Sohlberg and Mateer (2001) and Sohlberg and Turkstra (2011).

The relationship between sentence comprehension and EF is beginning to receive greater attention in the literature. If research continues to confirm that EF impairments are, in fact, related to sentence processing and/or comprehension, this would suggest that many populations may have sentence-level impairments that are subtle enough to be missed clinically but may affect educational and employment success. Continuing exploration of potential links between EF subprocesses and sentence comprehension and processing are necessary for understanding the interactions between cognitive and linguistic impairments as well as for motivating effective treatments. As this literature grows, it will become increasingly important for clinicians and researchers to have an awareness of the vocabulary and controversies associated with EF. Data collected by practicing clinicians on sentence comprehension in clients with EF impairments could contribute greatly to the current knowledge base on this important relationship.

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References


Complimentary Author PDF: Not for Broad Dissemination


## Appendix

### Sentence Comprehension Assessment Resources

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<td>Hammill, Brown, Larsen, &amp; Wiederholt, 1994</td>
<td>12–24</td>
<td>Listening/Grammar</td>
<td>Fourth edition no longer uses these subtests but includes Sentence Combining</td>
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<td>Sentence–Picture Matching: Auditory Version</td>
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<td>Sentence–Picture Matching: Written Version</td>
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<td>Northwestern Assessment of Verbs and Sentences</td>
<td>Cho-Reyes &amp; Thompson, 2012</td>
<td>Adults with aphasia</td>
<td>Argument Structure Production</td>
<td>Variety of sentence and verb structures Psycholinguistically controlled</td>
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<td>Psycholinguistic Assessment of Language Processing in Aphasia</td>
<td>Kay, Lesser, &amp; Coltheart, 2009</td>
<td>Adults</td>
<td>Argument Structure Production</td>
<td>Used informally due to lack of normative information</td>
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<tr>
<td>Comprehensive Assessment of Spoken Language</td>
<td>Carrow-Woolfolk, 1999</td>
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<td>Test of Linguistic Competence–Expanded</td>
<td>Wig &amp; Secord, 1989</td>
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