LSHSS

Clinical Focus

Wait…What??? Guiding Intervention Principles for Students With Verbal Working Memory Limitations

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Purpose: The purpose of this clinical focus article is to present 5 guiding principles for the development of interventions for children with limited verbal working memory abilities.
Method: Summarizing and synthesizing previously reported theories and empirical data, we present a framework intended to guide working memory interventions.
Results: Existing research and theory support a comprehensive, multidimensional treatment model that considers the knowledge and abilities of the student and the language-learning demands they face in the various contexts of a school day.
Conclusion: The clinical framework for which we are advocating is one that embodies the characteristics of complex interventions—those made up of many individual components that work synchronously in conjunction with each other.

Classrooms are challenging environments for students and teachers alike, and they pose real difficulties for students whose language development is atypical. All students are called on daily to listen, speak, read, write, calculate, and learn in often noisy and distracting school environments. Classroom interruptions call for shifts in attention and control of distraction (Leonard, 2001). Students must recall where they were in their thought process when the intercom goes off, a classmate acts out, or they lose themselves in an interesting but irrelevant thought—even for a brief moment. Many, but not all, students can get right back to what they were doing without any difficulty when they are interrupted. For some, however, momentary interruptions that break their concentration and disrupt their attention and engagement pose real difficulties when it comes to comprehension and learning. Such is the case for students with specific language impairment (SLI) and verbal working memory limitations.[1]

Our working memory is dedicated to holding in mind and mentally manipulating information for short periods of time so that we can use that information for a specific purpose (Baddeley & Hitch, 1974; Gathercole & Baddeley, 1993). As summarized by Adams, Nguyen, and Cowan (2018), some theoretical accounts of working memory distinguish between auditory/verbal versus visual/spatial mechanisms of storage. Verbal working memory has been found to be particularly vulnerable in children with SLI, resulting in pronounced difficulties with phonological memory and syntactic comprehension (Gillam, Montgomery, Gillam, & Evans, 2017; Kidd, 2013).

Verbal Working Memory and Executive Functions

Working memory takes its place among other core cognitive processes that constitute our executive functions. This multidimensional construct consists of a set of mental operations that allow individuals to disengage from the context at hand so that they can reference the mental models

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[1]In keeping with Bishop (2014), we use the term *specific language impairment* (SLI) to refer to children who have unexplained problems with language development that are severe and unlikely to go away on their own. In accordance with this view, the word *specific* is intended to mean idiopathic (i.e., of unknown origin) rather than exclusive to language only. We recognize that biological and environmental factors influence a child's language development and that children with SLI also experience problems in nonlinguistic domains (e.g., attention and nonverbal processing). When present, those co-occurring challenges do not fully account for the nature or severity of the presenting language problems.

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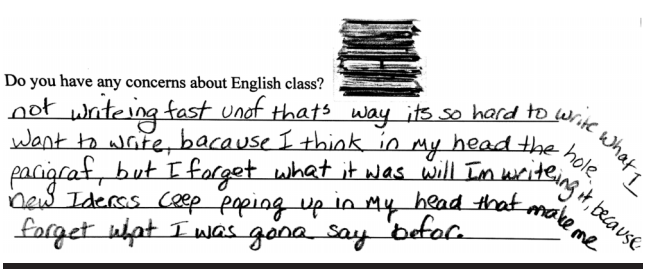
needed to guide their behavior toward achieving future goals (Hughes, Russell, & Robbins, 1994). We engage our executive functions when setting out to do things intentionally—change a tire, join a group activity on the playground, clean our room, or write an essay. "Doing school" requires us to act deliberately and with intention—all day, every day. Thus, participation in school taxes our executive functions.

Ample evidence is emerging that "there is no unitary executive function" (Stuss & Alexander, 2000, p. 289; Miyake et al., 2000). While ongoing research continues to inform the exact mental operations that constitute our executive functions, there is general agreement among researchers that inhibition, working memory, planning, organization, and regulatory processes are among the core mental operations that allow us to engage in goal-oriented behavior (Bashir & Singer, 2006; Lyon & Krasnegor, 1996; Singer & Bashir, 1999, 2016). Each of the component executive functions develops along its own trajectory, and dissociations among them may appear at any age (Best & Miller, 2010; Brocki, Fan, & Fossella, 2008; Singer & Bashir, 2016; Stuss & Alexander, 2000). Accordingly, one can be pretty adept at planning but struggle with inhibition, which may lead to impulsive and disorganized approaches to problem solving, or inhibition may be relatively intact, but working memory limitations may significantly limit the amount of information that can be held in mind, constraining language comprehension and expression and, in turn, academic achievement (Singer, 2016). The influence of working memory limitations on achievement is evident in the comments of a sixth-grade student, whose teacher asked her to share her concerns about English class on the first day of school (see Figure 1).

Recently, we see distinctions in the literature between empirical tasks assessing working memory capacity (i.e., the amount of information that can be stored temporarily in mind) and executive working memory (i.e., the active processing of that information with the support of attention and other executive control processes, such as organization; Fougnie, 2008; Marton, 2008). These distinctions are important, as performance differences in children are apparent across different kinds of verbal working memory tasks.

Figure 1. A sixth-grade student's concern about English class: "not writing fast enough that's why it's so hard to write what I want to write, because I think in my head the whole paragraph, but I forget what it was while I'm writing it, because new ideas keep popping up in my head that make me forget what I was gonna say before" (spelling corrected).



Simple span tasks require short-term storage of digits, words, word strings, or sentences for verbatim repetition. More complex are tasks that require simultaneous storage and active processing (e.g., comprehension of individual sentences followed by recall of the last word in each sentence presented). Performance on the latter may be influenced not only by working memory capacity but also by attention, the cognitive load of the processing task, the use of executive control strategies for remembering, and familiarity with the phonological, semantic, and syntactic features of the information being processed (Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; Gillam et al., 2017; Kidd, 2013; Swanson, 2017).

Consider, for example, how much more difficult it is to repeat words and sentences in a language you do not know as opposed to the one you have spoken your whole life and how much harder it is to remember and jot down someone's phone number if you first have to hunt around in your bag for a pen. Gillam et al. (2017) offer a thorough review of the literature supporting the notion that children with SLI differ from typically developing children in their use of cognitive schemas for processing, organizing, and chunking language in working memory and in their regulation of attention. These differences significantly constrain their ability to fully represent the phonological structure of words, learn language, and comprehend syntactically complex information.

Ample literature shows that other cognitive systems, such as attention, fluid reasoning, and visual–spatial processing work in concert with executive functions and language to support problem solving and goal attainment (Pintrich, 2000; Singer & Bashir, 1999; Vygotsky, 1962). Though formal assessment via highly controlled tasks might identify students whose discrete skills in these areas are underdeveloped, one must only step into a classroom to appreciate how quickly the "walls" between these skills evaporate as students must seamlessly recruit and integrate so many different cognitive and linguistic systems simultaneously in the name of learning. In day-to-day life, and certainly within a classroom, clinicians and teachers must appreciate how working memory both constrains and is constrained by other aspects of cognition, language, and experience.

Intervention for Verbal Working Memory

When it comes to intervention, then, working memory must be treated as an element in a biological system that is sensitive to the efficiency of other systems for its integrity. Research continues to shed light on the ways in which working memory is both supported and constrained by information and schemas stored in long-term memory (Cowan, 2014), attention (Fougnie, 2008; Marton, 2008), processing speed (Leonard et al., 2007; Montgomery & Windsor, 2007), task-specific contextual information (Soederberg Miller, Cohen, & Wingfield, 2006), intelligence (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Swanson, 2008), other executive functions (Barrouillet et al., 2007), emotions (Moran, 2016), and even fluctuations

throughout the day (Dirk & Schmiedek, 2016). We are still in the process of understanding the nature of verbal working memory, its development, and how working memory limitations affect language and learning across the life span.

There is a paucity of evidence-based intervention for working memory and, particularly, for verbal working memory. As such, clinicians working with school-age students have little at their fingertips when it comes to choosing proven, replicable interventions for students in their care. Classrooms are complex environments that tax language, executive, memory, regulatory, and cognitive processing in myriad ways that defy simplistic, prepackaged, or one-size-fits-all treatment models. The purpose of this article is to present five guiding principles that frame the development of interventions for verbal working memory. These are informed by both theory and research. We argue for a comprehensive, multidimensional treatment model that considers the knowledge and abilities of the student and the language-learning demands that the student faces in the various contexts of a school day. The clinical framework for which we are advocating is one that embodies the characteristics of complex interventions—those made up of many individual components that work synchronously in conjunction with each other to bring about desired outcomes (Broer, Bal, & Pickersgill, 2017; Brown, 1992; Medical Research Council, 2006).

Principle 1: The Underlying Neurodevelopmental Status and the Absolute Capacity of Working Memory Cannot Be Directly Manipulated to Improve Contextualized Language Processing

In recent years, commercial products have emerged that claim to increase working memory capacity by having the user practice a variety of working memory "games." Much hope has been placed on computer-based training programs, such as CogMed (Pearson Education), Jungle Memory (Memosyne Ltd.), and others, as a way to improve basic cognitive functions like working memory through computerized practice activities. The notion behind these programs is that repeated practice (or "training") with tasks that tax working memory along a continuum of difficulty will, over time, increase the capacity of working memory—much like physical training with lifting weight will build muscle bulk and strength.

As appealing as this notion is, recent literature reviews and meta-analyses (Melby-Lervåg & Hulme, 2013; Shipstead, Redick, & Engle, 2012) have cast doubt on the idea that computer-based working memory training improves working memory capacity. Looking at the results of over 130 published studies, Daniel Simons is quoted by Hamilton (2016) as saying, "It would be really nice if you could play some games and have it radically change your cognitive abilities… the studies don't show that on objectively-measured real world outcomes." Until researchers assess memory with tasks that are entirely different than the ones that were used to "train" and assess memory as a discrete skill, we can only conclude that computerized training improves a subset of memory functions in measurable ways.

Some studies show greater working memory performance on novel tasks of working memory following the use of computer training programs (e.g., Holmes et al., 2010); however, no studies of computerized training have demonstrated clear transfer to other, more academically relevant reasoning or problem solving tasks that tax working memory. Moreover, there is meager evidence that such training generalizes to day-to-day academic or real-time language processing abilities. With practice, one can get better at performing the kinds of memory tasks included in computer-based programs, but these gains do not necessarily transfer to being able to take notes in history class or keep a thesis statement in mind while writing a 10-page paper. Melby-Lervåg and Hulme (2013) conclude that "There is no evidence that these programs are suitable methods of treatment for children with developmental cognitive disorders" (p. 283).

Speech-language pathologists (SLPs) must turn to more dynamic intervention approaches that are grounded in an appreciation of the complex listening, speaking, reading, mathematics, writing, problem solving, and social interaction demands that children with SLI face across their school day. Students must recruit verbal working memory and other cognitive and linguistic resources in a synchronous manner if they are to manage the many tasks of learning in school. The use of decontextualized, computer-based treatment approaches that are aimed to increase the verbal working memory capacity of children with SLI is not likely to transfer to authentic language learning contexts. As such, SLPs must look to other treatment approaches to support students with verbal working memory limitations.

Principle 2: Increasing Efficiency and Automaticity With Language Frees Up Resources in Working Memory; in Turn, This Functionally Improves Working Memory Capacity

Children with SLI are well known to have difficulty acquiring the patterns of language simply through exposure to adults who use language fluently. Despite having average intelligence, they fail to internalize the phonological, morphological, syntactic, semantic, and pragmatic "patterns" that underlie spoken communication, and they exhibit processing differences in long-term memory and verbal working memory that interfere with processing efficiency (Lahey & Bloom, 1994). As a result, their ability to understand and formulate language requires collaborative attention, storage, coordination, and problem-solving processes; therefore, listening and speaking both recruit and place a load on working memory (Gillam et al., 2017).

The amount of information that can be held in working memory is known to be limited to 4 ± 1 meaningful units for up to 30 s (Cowan, 2001; Miller, 1956), and we see no evidence in the literature that the absolute capacity

of verbal working memory can be altered. However, Gillam et al. (2017) present a compelling argument that the challenge children with SLI face with working memory tasks is not one of capacity alone. Instead, they argue that memory capacity results from the dynamic interaction between language knowledge, prior language-learning history, and the ability in any given moment to selectively attend to and process incoming information (Gillam et al., 2017). In other words, rather than being a "fixed entity," working memory capacity varies in accordance with

- *the who*: the knowledge and processing skills and abilities of the individual at any given time;
- *the what*: the type of information the student must remember and the degree to which that information is familiar;
- *the how*: the processing demands of the task (i.e., the concomitant demands for inhibition, attention, emotional regulation); and
- *the where*: the characteristics of the learning environment.

The overarching goal of intervention is to increase awareness of and automaticity with fundamental patterns of language so as to functionally "free up" resources for active processing. For example, for struggling readers, intervention goals focused on improving phonological and phonemic awareness serve to facilitate decoding ability; in turn, automaticity of decoding facilitates fluent reading (National Reading Panel, 2000). Wolf & Katzir-Cohen (2001) argue that, as fundamental reading processes are automatized, the mental effort and attentional resources required for word recognition lessen, thereby allowing the reader to devote cognitive resources to comprehension monitoring, which demands working memory.

In terms of intervention, this same notion extends to other levels and features of language as well. Research shows that the relationship between knowledge of various domains of language is related to—and in some cases predictive of—spoken language comprehension and reading comprehension abilities. Children with SLI are known to have deficits not only with working memory but also with syntax (Gillam & Johnston, 1992; Singer, 1997; Scott, 2009), which plays a central role in both listening and reading comprehension (Brimo, Apel, & Fountain, 2017). Ample research shows that children with SLI struggle with comprehending not only simple sentence structures that follow a subject–verb–object pattern but also more complex sentences (e.g., those with passive and relative clause structures). These place even greater demands on verbal working memory because they require that information be held in mind until it can be coordinated with propositions that appear much later in the sentence.

One must only open a fourth-grade science textbook or read the front page of a newspaper to confirm that the number of ideas conveyed in complex sentence structures typical of expository text routinely exceeds the well-established capacity limit of verbal working memory (i.e., three to four chunks of information). Consider, for example, the following two sentences from the front page of the *New York Times* in 1995:

> "Orenthal James Simpson, a man who overcame the spindly legs left by a childhood case of rickets to run to fame and fortune, surmounted a very different sort of obstacle today, when a jury of 10 women and 2 men cleared him of charges that he murdered his former wife and one of her friends. The verdict, coming 16 months after Nicole Brown Simpson and Ronald L. Goldman were slashed to death in the front yard of Mrs. Simpson's condominium and after 9 months of what often seemed like interminable testimony, sidebars and high-priced legal bickering, was reached in the end with breathtaking speed." (Margolick, 1995, October 4)

Whereas individuals with intact language processing abilities are capable of understanding sentences like these, comprehension of lengthy sentences must be informed by something other than working memory (Gillam et al., 2017). We can only surmise that knowing something about how appositive structures interrupt the subject–verb relationship in a sentence assists a reader in holding that subject in mind amidst the "noise" of the appositive long enough to relate the subject to the verb. When syntactic knowledge is lacking, readers must devote cognitive resources to the act of comprehending, perhaps engaging more executive control as they deploy strategies to access propositional content (i.e., by rereading and/or parsing a sentence chunk by chunk). Perhaps, this is why intervention targeting syntax knowledge has resulted in improved reading comprehension in children (Weaver, 1979). Direct intervention designed to strengthen morphology also has been shown to improve literacy achievement, phonological and morphological awareness, vocabulary, reading comprehension, and spelling for students with reading, learning, and speech and language disabilities (Goodwin & Ahn, 2010; Kirk & Gillon, 2009). The implication is that children with SLI who have stored knowledge about these aspects of language recognize linguistic patterns more readily, thereby alleviating executive working memory demands for language processing.

When it comes to working memory intervention, we see processing efficiency resulting (at least in part) from secure linguistic knowledge and rich mental schemas. Children who are lacking or simply insecure in their knowledge of language need intervention designed to strengthen their awareness of how the "nuts and bolts" of language work. In this regard, intervention for children with working memory limitations should aim to heighten metalinguistic awareness and firmly establish language knowledge in long-term memory so as to facilitate greater automaticity with language processing. As Ericsson and Delaney (1999) suggest, increased experience with a domain of processing supports the development of a more sophisticated repertoire of strategies and more efficient knowledge representations, which, in turn, forges greater capacity and flexibility.

From this perspective, in designing intervention for working memory, one component of treatment should include proven interventions that target various aspects of language. Resources are available to SLPs that target the development of vocabulary (Bos & Anders, 1990; Bryant, Goodwin, & Bryant, 2003), morphology (Wolter & Green, 2013), syntax (Saddler & Graham, 2005; Scott & Balthazar, 2008; Singer & Tamborella, 2018; Tamborella & Singer, 2015), narrative comprehension and formulation (Gillam, Hartzheim, Studenka, Simonsmeier, & Gillam, 2015; Peterson, Gillam, Spencer, & Gillam, 2010; Swanson, Fey, Mills, & Hood, 2005), spoken and written discourse (Bashir & Singer, 2006; Singer & Bashir, 1999), and disciplinary literacy (Derewianka & Jones, 2016; Fang & Schleppegrel, 2008). For research-supported treatment approaches that span across multiple domains of language, see also McCauley, Fey, and Gillam (2016); Cirrin and Gillam (2008); Gillam, Gillam, and Reece (2012); Ukrainetz (2006); and Ukrainetz (2014).

Principle 3: Storage and Effective Processing of Verbal Information in Working Memory Can Be Supported Through the Use of Visual Anchors That Serve to Make Language Stand Still

Rehearsal and Visualization

Interventions designed to harness visual imagery in support of verbal working memory have been shown empirically to be effective. As such, the use of visual anchors as tools for intervention holds promise for clinicians working with students who have working memory limitations. In an effort to improve the ability of elementary school children with SLI to remember and follow oral directions, Gill, Klecan-Aker, Roberts, and Fredenburg (2003) compared three different interventions, all of which were provided for two 15-min sessions per week. Experimental groups were taught to use either a rehearsal strategy or a rehearsal/visualization strategy. A control group received the same amount of traditional language therapy that targeted relevant semantic and syntactic structures through direct instruction, modeling, and practice. After 5 weeks of intervention (10 sessions), both groups receiving strategy instruction showed significant improvement relative to the control group in following complex directions. Results suggested that both types of rehearsal strategies improved children's ability to follow directions. Long term, however, the group using only the rehearsal strategy did not maintain their significant advantage over the control group. Eight months following treatment, only the group taught to use the rehearsal/visualization strategy retained improved performance. The investigators hypothesized that the simultaneous provision of verbal and visual information allowed for more integrated information processing, that visual imagery tapped the relative strengths of children with SLI, and/or that interest and sustained attention were enhanced through the relative permanence of visual information.

Given how frequently students must execute spoken directions in the classroom, school-based SLPs can take heart in these findings. While students in Grades 1 through 5 were included in the Gill et al. (2003) study, we have no reason to believe that these methods would not be equally effective with older students as well. Moreover, the intervention protocols in this study would be easy to use within individual, small group, and/or classroom-based settings. As such, this study provides empirical support for the use of strategic instruction pairing rehearsal with visualization to enhance students' ability to hold increasingly complex verbal directions in working memory long enough to execute them in a classroom setting. Along similar lines, students can be taught to close their eyes when executing tasks that tax working memory, as this also has been shown to heighten their performance (Vredveldt, Hitch, & Baddeley, 2011). Intervention strategies such as these should not be taught in isolation for the sake of "working on working memory." Rather, intervention should introduce strategies that maximize students' ability to use language to participate successfully in authentic learning experiences that tax working memory.

Advance Organizers

Along similar lines, visual–spatial strategies that serve to represent concepts in graphical form have been shown to alleviate demands on working memory and, in turn, support language processing. As far back as 1926, Morrison recommended that educators introduce new information in the form of a sketch that conveys the essence of a lesson. Advance organizers are one type of graphic that depict the hierarchical arrangement of key concepts and ideas visually prior to learning (i.e., the main topic and subordinate concepts). Evidence suggests that advance organizers have positive effects when learning and retention are assessed immediately following instruction (Luiten, Ames, & Ackerson, 1980). Presumably, this occurs because the visual schema represents both the key vocabulary and the organization of the instructional discourse. In that sense, it provides a visual framework that has the potential to support listening.

Whether and/or how advance organizers support working memory in particular and its role in "real-time" language processing remains an unanswered question. In learning, the formation of new concepts results when new information and existing concepts are bound together, and the "cauldron [for concept formation] is assumed to be working memory" (Cowan, 2014, p. 210). Further research is necessary to determine whether providing students with a visual schema of key concepts in advance of their learning helps them focus their attention on new information and fuse it with what they already know.

Graphic Organizers

Graphic organizers (GOs) differ from advance organizers in that they visually portray not only key concepts (i.e., vocabulary) but also the relationships between those concepts, which may or may not be hierarchical in nature. Not all GOs are created equally; however, concept maps, semantic maps, visual displays, and visual tools are unique,

and as such, each of these graphic displays depicts a specific organizing schema (Dexter & Hughes, 2011; Hyerle, 1996). Studies examining the effectiveness of GOs on learning vary in a number of ways that obscure our understanding of whether and how they support students' working memory. Such variations include the degree to which the visual organization of the graphic matches the organization of the discourse it represents, who is constructing the graphic (i.e., the teacher, the student, or both), and whether the graphic is being constructed before, during, or after listening or reading. Further research is warranted to examine these variables and identify the conditions under which GOs are most effective when it comes to supporting working memory, facilitating comprehension of academic content, and enhancing recall of newly learned information. As DiCecco and Gleason (2002) note, "The empirical support for the use of GOs in K-12 classrooms is particularly mixed… However, the appeal of GOs and the intuitive sense that they ought to work has often overshadowed the question of their empirical efficacy" (p. 307).

From the standpoint of designing working memory intervention and helping students "do school," the use of graphics for anchoring spoken and written language continues to have clinical promise. In our view, the power of GOs is rooted in their ability to visually represent linguistic information within visual frameworks that "hold" language externally for a student. By referencing visual–spatial representations of language that are static, students can actively process and (if necessary) manipulate the information conveyed within them before it decays from working memory. Robinson, Robinson, and Katayama (1999) suggest that "text outlines are stored in memory in verbal format, whereas graphic organizers are stored spatially" (p. 52); therefore, the facilitative effects of some types of GOs on comprehension may be due to the fact that information displayed spatially does not compete for limited verbal working memory resources. Further research is needed to shed light on the types of graphics that are most effective and how they support working memory, spoken and written language comprehension, spoken and written discourse, and long-term retention of academic content.

In keeping with the notion that static, graphical representations of language hold promise for supporting students with real-time language processing, Singer and Bashir (2000) developed a set of six graphics called *Brain Frames*. Each of the six graphics visually represents the underlying pattern (or schema) of a specific propositional discourse (e.g., sequencing, showing causes/effects, comparing/contrasting, showing relationships, categorizing, and telling). Brain Frames differ from traditional GOs in the same way that Hyerle's (1996) Thinking Maps do. Rather than fill in predrawn boxes or bubbles on a premade worksheet, students construct their own Brain Frames by hand. Thus, they take ownership of generating the ideational content, organizing that content within a visual–spatial pattern, and conveying the relationships between the ideas. In doing so, they represent their thoughts within a visual schema or "frame" that develops over time as information is actively processed. See Figures 2 and 3 for examples of two Brain Frames, which were constructed by a fifth-grade student doing research on Jimi Hendrix for a biography project.

In contrast to representing information as a visual–spatial sequence (shown in Figure 2), consider this same information in traditional outline form (shown in Table 1). Though these images are composed of the exact same words, their visual–spatial organization is dramatically different, and each conveys something about the information that is independent of the content. Figure 2 "looks" like a sequence of events unfolding over time, whereas Table 1 looks like ideas that are categorized hierarchically.

Cowan (2014) asserts that "when there are not yet sufficient associations between the elements of a body of material, working memory is taxed until the material can be logically organized into a coherent structure" (p. 212). We suspect that, when the visual–spatial organization of a graphic transparently represents the ideational content that it conveys, it lends support to students' working memory by illustrating ideational patterns and the relationships between ideas. This is an area of inquiry that is ripe for further research.

Awareness of the patterns that underlie language and thought is largely unconscious to most people, but it directly influences clarity of communication and academic success (Hyerle, 1996; Singer & Bashir, 1999). The use of GOs with children with SLI has the potential to influence effectiveness of language processing by way of increasing metalinguistic awareness of discourse patterns, anchoring and representing them visually. Although we do not yet have quantitative data that shed light on the effects of using such visual strategies on children's working memory performance, our clinical work with school-age and college students over the last 20 years and research on the effectiveness of constructing curriculum maps in real time over the course of a lesson (Lenz, Adams, Bulgren, Pouliot, & Laraux, 2007) suggests that such strategies serve as "externalized working memory spaces" for students. They allow students to store information by moving it outside of their heads and into a visual–spatial pattern that stays still on paper. Doing so enables them to reflect on, update, and manipulate elements of language. Graphics may support deeper conceptual understanding and greater facility with the foundational elements of language when used as tools for extracting key ideas from listening or text and/or generating and organizing thoughts prior to speaking or writing (Singer & Bashir, 1999). To that end, GOs may functionally support students' verbal working memory in tasks with high language and memory demands.

Principle 4: The Verbal Working Memory Demands of Real-Time Language Processing Can Be Supported by Heightening Linguistic Structure and Salience

All of us can recall a time when we sat in class listening to a teacher who spoke too quickly, was too disorganized for us to follow, or presented ideas that were too complicated for us to grasp. In the face of processing demands that exceed

Figure 2. A Sequencing Brain Frame constructed by a fifth-grade student while conducting research for a biography project on Jimi Hendrix. The important events in Jimi Hendrix's life are represented in boxes, with arrows connecting them to show the sequence of events. Relevant details about those events are represented in circles attached to the boxes.

Figure 3. A Showing Causes/Effects Brain Frame constructed by a fifth-grade student while conducting research for a biography project on Jimi Hendrix. The main event under scrutiny is in the center box (in this case, Jimi Hendrix being "in the army"). Causal events are in boxes to the left of the main event, and effects are in boxes to the right of the main event. Arrows show how the events are related (i.e., causes lead to the main event, and the main event leads to multiple later events). Thought bubbles are used to capture associated thoughts/ideas—in essence, metacognitive afterthoughts about items in the Frame. In this case, the thought that Hendrix was a terrible soldier hovers over the main event of Hendrix being in the army. Also, the names of songs Hendrix wrote hover over the life events and beliefs that the student thought may have inspired them.

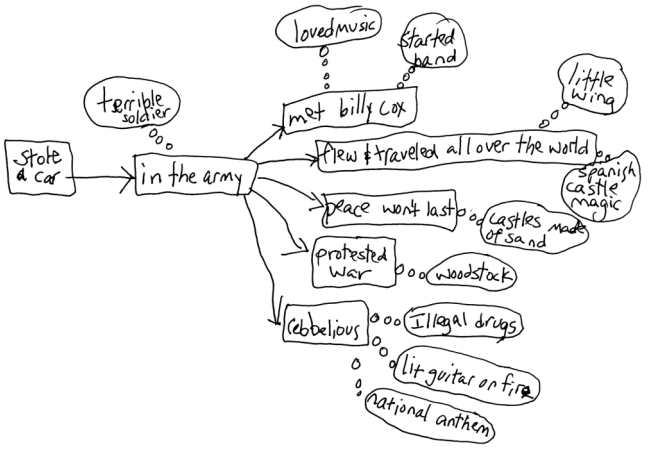


Table 1. The information conveyed in Figure 2 depicted in traditional outline form.

I. Got first guitar
  A. 12
  B. From Dad's friend, 15
  C. Acoustic
II. Lessons
  A. Two lessons from my dad
  B. Quit because I refused to play right-handed
III. Dad bought first electric guitar
  A. 15
  B. White and blue
IV. Taught myself to play
  A. Influences: BB King, Little Richard, Muddy Waters, Elvis, Screamin' Jay Hawkins, T-Bone Walker, Little Walter
V. In army
VI. Formed a band
  A. 20
  B. The King Casuals
VII. Session guitarist
  A. Tons of practice
VIII. The Jimi Hendrix Experience
IX. Took risks
  A. Fast playing
  B. Tricks on stage
X. Went on tour with famous bands
  A. The Who, Cream, The Monkeys, The Beatles, The Rolling Stones
  B. Mixed it up
  C. Different sound

our capacity, a feeling of being overwhelmed arises in an instant. All students experience that moment at some point in their education, and in it, the only viable response seems to be, "Wait… what???" Students either search for a way to repair the breakdown (e.g., by asking for repetition) or simply give up, resigning themselves to the fact that they cannot keep up and have no idea what was said. That experience is one that children with SLI encounter daily in the classroom, in their social interactions, or both. It is the moment when their verbal working memory fails them.

External Language Factors That Influence Verbal Working Memory

Students cannot understand what they do not remember, and they cannot remember what they do not understand. Consequently, the manner in which people speak and write has profound effects on comprehension and learning. Accordingly, school-based clinicians must attend to the inherent memory and language weaknesses of their students and the manner in which language is used instructionally. As the latter also affects students' ability to engage in learning, tending to this dimension when developing interventions for working memory is important.

We can find no formal research that explores how speaking style influences verbal working memory performance. What is known about the architecture of verbal working memory, however, allows us to make reasoned inferences about how to alter the way in which we speak in an instructional context so as to accommodate students with limitations in working memory. It is intuitive that educators and SLPs need to monitor and adjust such things as their

- rate of speech,
- use of emphatic stress to highlight key words,
- utterance length,
- semantic and syntactic complexity,
- use of sentence parsing with micropauses to highlight functional grammatical elements, and
- use of gestures to visually emphasize and anchor meaning.

Indeed, recommendations such as these are often made in the literature on working memory intervention (Boudreau & Costanza-Smith, 2011), yet the evidence behind these recommendations does not exist to date.

In addition to adjusting speaking style, educators and SLPs must monitor students' comprehension in real time and adjust their discourse to accommodate working memory limitations (e.g., repeating concepts and building content redundancy so as to "refresh" the information and/or by clustering information into meaningful "chunks" to support efficient storage and processing). By simply adjusting the way in which adults talk to students, they may minimize breakdowns in language processing that are rooted in verbal working memory.

Internal Language Factors That Influence Verbal Working Memory

By the same token, SLPs must recognize the verbal working memory underpinnings of students' language formulation, though scant research has examined this relationship to date. Slevc's (2011) research shows that working memory works in concert with lexical accessibility to influence syntactic structure and the order in which information unfolds in a sentence. He notes that, "Because speaking requires the production of non-linear conceptual information as a linear order of words, speakers must maintain information [in working memory] that is otherwise ready to be produced" (p. 1511). The need to maintain ideas in mind influences sentence formulation and the formulation of connected discourse (e.g., monologues and narratives; Singer & Bashir, 1999). Speakers must continually maintain and update what they intend to say, what they have already said, and what they have yet to say as their discourse unfolds in real time. Thus, conversation and spoken monologues tax verbal working memory considerably.

Discourse monitoring and updating in working memory is particularly difficult for children with SLI, whose language is characterized by false starts, mazes, abandoned utterances, repetitions, and ambiguous pronoun referents (Befi-Lopez, Caceres-Assenco, Marques, & Veira, 2014; Whitely & Colozzo, 2013). Interventions that incorporate visual anchors to support students with constructing schemas for discourse have been shown to support students with language formulation beyond the single sentence level (Gillam & Gillam, 2016; Singer & Bashir, 1999). As such, SLPs should consider the use of such strategies when designing treatment to support the expressive language of children with SLI and working memory limitations.

Principle 5: Professional Collaboration Should Seek to Identify Factors That Influence Student Performance and, in Turn, Accommodate Students' Verbal Working Memory Limitations Across Different Language and Learning Contexts

School-based SLPs are responsible for addressing the linguistic and metalinguistic foundations of curriculum learning for students with disabilities and students who are struggling academically or at risk for school failure. Given their expertise in communication and language, their responsibilities also include collaborating with teachers, educational specialists, and paraprofessionals to enhance student performance in school (American Speech-Language-Hearing Association, 2010). As such, SLPs have a rightful role in classrooms, as they can offer valuable insight about the language underpinnings of curriculum (Ehren, 2012) and the capacity of students to meet the linguistic and processing demands of academic tasks. In keeping with this collaborative role, SLPs are in a position to provide much-needed professional development for colleagues in other disciplines (Boudreau & Costanza-Smith, 2011). These colleagues may have very little understanding of how language and verbal

working memory systems both constrain and are constrained by attention, cognition, executive functions, and self-regulation systems. Similarly, they may lack insight into how all of these systems influence students' language and academic performance and their experience of themselves as learners.

External Factors That Influence Verbal Working Memory

In designing collaborative interventions, SLPs must consider the ways in which external factors (e.g., environment, context, task) influence students' processing and classroom performance. Consider, for example, how classroom interruptions may break concentration, causing students to lose track of what they are holding in mind and what they are doing. Leonard (2001) surveyed 1,000 classroom teachers in 472 different schools to determine the nature and frequency of external interruptions to teaching. The most frequent interruptions were unexpected intrusions from the intercom (80.2%), message deliveries (36.9%), and visitors (31.7%). Some teachers and students are not bothered by these intrusions, but others are. For students with SLI, intrusions may vie for attentional resources and disrupt the ability to hold and maintain information in verbal working memory. Classroom-based intervention may be required to address this interfering factor. Teachers, paraprofessionals, and SLPs should monitor the negative effect of intrusions and, as needed, re-orient students to the task at hand following the interruption (e.g., by resecuring the student's attention, providing repetition, and refreshing the information with which the student was engaged).

Background noise is a second environmental factor shown to tax verbal working memory. Frequently, multiple learning groups are talking and working simultaneously within classrooms, which contribute to a busy and noisy learning environment. Chairs scrape, pencil sharpeners whirl, and students in neighboring groups get excited and talk loudly. A very small body of research shows that children demonstrate individual differences in their ability to perform verbal working memory tasks in the presence of competing "to-be-ignored speech" (Sörqvist & Rönnberg, 2010, p. 216). Students with low working memory capacity are particularly sensitive to noise interference when performing more complex language comprehension tasks (Sullivan, Osman, & Schafer, 2015). As such, students with SLI and verbal working memory limitations are at high risk for comprehension breakdowns in settings that have high levels of background noise.

Background noise is a challenging environmental factor to manage clinically, especially in schools with open classroom environments. SLPs may be able to do little to control classroom noise, but they should collaborate with teachers to identify students who are particularly derailed by it. No empirical studies directly guide intervention in this area. However, we can offer some recommended treatment practices that are informed by current research. For one, teachers and SLPs should work together and mindfully design the learning environment in such a way as to minimize the negative effects of noise on students' language processing. In addition, they should consider where to provide intervention for those students who are highly sensitive to background noise, for some will not perform well when intervention is offered in a pull-aside group within the classroom. Through teamwork and thoughtful intervention programming, SLPs can collaborate to mitigate the influence of the environment on students' verbal working memory.

An additional factor that is external to students and known to influence verbal working memory abilities is the processing burden of a task. Such elements as task familiarity and the presence or absence of pressure on students for rapid and/or accurate responses can increase the mental load of a task, rendering the need for increased mental effort. Together, mental load and mental effort comprise what Paas and Van Merriënboer (1994) refer to as cognitive load. Tasks that have high cognitive load are inherently complex. In a typical school day, children encounter countless complex tasks with high cognitive load. They take timed math tests, follow and participate in literature circles, peer edit other students' papers, and give oral presentations. All of these tasks have unique executive, working memory, attention, regulatory, cognitive, and linguistic demands. Consequently, consideration of task complexity and cognitive load is important when designing intervention for verbal working memory in all settings.

Complex tasks require the smooth integration of several component skills, some of which are consistent across tasks (e.g., sentences always start with a capital letter), and some of which vary depending on the task at hand (e.g., sentence structure varies according to genre and content discipline; Derewianka & Jones, 2016; Paas & Van Merriënboer, 1994). Whereas complex tasks are characterized by hierarchies of goals and subgoals, students must attend to, keep track of, and monitor goals and subgoals in real time as they work. To solve a math word problem, take notes during a lecture, or write a research paper, students must sequence their thinking, language, and behavior, keeping track of what there is to do, what they have ready done, and where they are going. Verbal working memory plays a central role in these aspects of doing school, as multiple elements must be held, refreshed, and updated in mind over time.

In terms of intervention, SLPs should consider the cognitive load imposed by the spoken and written language that students encounter across the various settings of a school day. More time and mental effort is required to understand spoken and written sentences that (a) are composed of a high number of propositions or embeddings, (b) have elements that are not in the expected subject–verb–object order, or (c) have crucial elements that are far apart (King & Just, 1991; Montgomery, this issue; Thompson & Shapiro, 2007). Verbal working memory holds the key to unlocking lengthy and complex sentences, as words, phrases, and clauses must be held in mind long enough to be integrated and understood. In addition to enhancing students' linguistic and metalinguistic knowledge about how various sentence structures are formed (as we suggest in Principle 2), SLPs should collaborate with educators to modify curriculum

materials for students with SLI who lack the requisite language knowledge needed to access them. The goal is to decrease the linguistic complexity and, in turn, lighten the load on verbal working memory so that students can manage the language of school.

Though no formal research substantiates the effect of altering speaking style on working memory, SLPs may want to consider how teacher talk influences students' language processing. For example, some teachers naturally speak very quickly, offer little or no repetition or redundancy, and pack a lesson with numerous new vocabulary concepts, using few visuals to anchor their instruction. Other teachers, however, use a more moderate speaking rate, are redundant and repetitive in their presentation style, weave periodic summaries into lessons to consolidate new concepts, control the pace at which new terms are introduced, and augment their instruction with visual enhancements. Some teachers may be open to constructive suggestions for how to support the listening comprehension and learning of students with SLI by adjusting their discourse styles; some will not. Others may be, but they may not be able to monitor and alter their speaking style in real time while simultaneously attending to content delivery. The instructional discourse style of teachers is one parameter that should be considered when placing students with SLI and verbal working memory limitations in inclusive classroom settings. Research is needed to delineate the ways in which speaking style influences verbal working memory and student performance in classrooms.

Internal Language Factors That Influence Verbal Working Memory

Finally, intervention must consider the ways in which internal factors (e.g., emotions, motivation, engagement) influence students' language processing and school performance. A special concern is the role of anxiety and its influence on verbal working memory. A meta-analysis by Moran (2016) reveals that anxiety, whether self-reported or induced by complex task demands, restricts performance on verbal working memory tasks. Some children with SLI have concomitant trait-based anxiety disorders (Cantwell & Baker, 1991); therefore, they are particularly at risk for working memory limitations that are exacerbated by anxiety. These children require speech-language intervention that is coordinated with psychological services and supports. Our clinical experience of children with SLI reveals that they develop an increasing awareness of their language limitations through childhood and, especially, by the middle school years. This awareness can lead to situationally induced social anxiety (Baker & Cantwell, 1987; Beitchman et al., 2001; Cantwell & Baker, 1991). Students know their language limits, and when verbal working memory, language processing, and language formulation demands of a given academic task or social interaction exceed their abilities, they become anxious.

Anxiety can interfere with the ability to recruit the attention, executive function, and working memory resources needed to mediate and manage language demands in real time (Moran, 2016). Comprehensive intervention for children with SLI, then, requires a thoughtful collaboration between the SLP, students' classroom teachers, school psychologists and, as needed, other mental health professionals.

A Framework for Intervention

The five principles that are discussed in this article form a framework to guide the development of intervention approaches for students with working memory limitations. Whether working with factors that are internal or external to the child, the ultimate goal of intervention for students with verbal working memory limitations is to (a) identify the underlying factors that constrain the students' performance, (b) teach students evidence-based tactics and strategies for meeting working memory and task demands, (c) implement appropriate classroom accommodations, and (d) modify instruction and task demands to diminish factors that are constraining verbal working memory. All professionals should acknowledge the student's experience explicitly, demystify the source(s) of their distress, and collaborate to assess the effectiveness of interventions over time. To this end, Table 2 outlines a framework for the design of intervention for working memory that encompasses the five principles outlined above.

Conclusion

Verbal working memory is a complex, dynamic, multifaceted system that works in concert with other equally complex, dynamic, and multifaceted systems—attention, language, cognition, executive functions, and emotions. Intervention approaches for working memory must appreciate its inherent complexity. As Westby so eloquently stated in 1997,

> "As students move through school, they experience changes from two directions: inside-out and outside-in. From the inside-out, they develop more elaborate cognitive, metacognitive, and linguistic abilities; increased working memory capacity; and increased speed of processing to bring to the school curriculum. From the outside-in, they encounter increasingly abstract academic content and expectations to become increasingly responsible for monitoring their own behavior and organizing their own learning." (p. 285)

There is no quick and easy fix for verbal working memory limitations, and evidence-based interventions that address the real-time challenges that children with verbal working memory restrictions experience in school are sorely lacking.

We argue here for a comprehensive, multidimensional treatment model that considers both the knowledge and abilities of the student and the language-learning demands that they face in the various contexts of a school day. The clinical framework for which we are advocating is one that embodies the characteristics of complex interventions—those made up of many individual components that work synchronously in conjunction with each other. Because

Table 2. An integrated framework for verbal working memory intervention.

Guiding questions for intervention	Treatment considerations
What are the working memory demands of the language/learning task?	• Amount of information to be stored temporarily • Amount and type of active processing required • Nature and number of competing attentional demands
Does the student have the requisite knowledge and abilities to manage the task demands?	• Cognition/reasoning • Language • Executive functions • Visual–spatial processing • Background knowledge • Working memory • Emotional regulation
Does the way in which information is presented need to be modified in order to support the student's success?	• Adjust speaking rate • Reduce length (volume of information, sentence length, discourse unit size) • Simplify semantic and/or syntactic complexity • Use visual representations or anchors • Modify the executive control demands
Are interpersonal supports needed to assist the student in compensating for working memory limitations?	• Repetition • Visual anchors • Gestural cues • Emphasis • Guiding or clarifying questions
Are changes to the environment needed to enhance the student's success?	• Decrease background noise • Limit competing visual distractions

working memory is complex and fluctuates from day to day and task to task (Dirk & Schmiedek, 2016; Lahey & Bloom, 1994), intervention that aims to improve it must also be complex and fluid.

The intervention approach we are suggesting through the guiding principles put forth above is sensitive to several dimensions of complexity (Medical Research Council, 2006). To begin with, the range of possible treatment outcomes is broad, as the expression of working memory limitations is quite varied across children and influenced by their unique strengths and challenges. Consequently, the number of key elements included in the treatment will vary from child to child on the basis of ever-changing developmental, curriculum, and situational demands. Accordingly, various professionals must be responsible for the design and delivery of different aspects of the intervention across a range of settings. We resonate with Brown (1992) when she says, "Components [of complex experimental designs] are rarely isolatable. The whole really is the sum of its parts. The learning effects are not even simple interactions, but highly interdependent outcomes of a complex social and cognitive intervention" (p. 166).

This kind of treatment approach calls for a blend of service delivery models, allowing the SLP to determine what kind of service delivery best supports the development of effective and efficient learning at any given time. It also demands interprofessional collaboration, for children spend the bulk of their days in classrooms where a multitude of demands face them as they move horizontally across subjects and vertically across grade levels. School-based practitioners must consider the linguistic and processing underpinnings of academic tasks that place high working memory demands on students and, in turn, design direct and consultative interventions to support students with language and working memory vulnerabilities.

Discourse comprehension and expression place constant demands on verbal working memory, as both require continuous holding, chunking, refreshing, updating, and consolidating (Alloway, 2009; Cowan, 2014; Whitely & Colozzo, 2013). Interventions for students with verbal working memory limitations that are in keeping with the principles we have outlined here are mindful of

- *the who*: the knowledge and processing skills and abilities of the individual at any given time;
- *the what*: the type of information the student must remember and the degree to which that information is familiar;
- *the how*: the processing demands of the task (i.e., the concomitant demands for inhibition, attention, and emotional regulation); and
- *the where*: the characteristics of the learning environment.

By accounting for these complexities in the design of intervention, SLPs can keep the "Wait…what???" moment at bay for students.

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