Sensitivity to Increased Task Demands: Contributions from Data-Driven and Conceptually Driven Information Processing Deficits

This article explores evidence related to the idea that children with language impairments present co-occurring limitations in data-driven and conceptually driven processing. Data-driven processing (also referred to as bottom-up processing) concerns the way auditory and visual information is received. Conceptually driven processing (also referred to as top-down processing) concerns the way higher-order thinking influences performance. Together, data-driven and conceptually driven processing limitations contribute to a heightened sensitivity to increasing task demands in children with language impairments. We present assessment and intervention suggestions that pertain to these difficulties. Key words: attention, central executive, information processing, language impairment, memory, perception

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JOHNSTON (1994) asserted that the critical mechanism underlying language development “is nothing more or less than the general information processing capabilities that constitute the mind” (p.108). One implication of her point is that children with language impairment (LI) have fewer cognitive resources to allocate to any task, including language development. This paper explores evidence from studies of attention, perception, memory, discourse processing, and literacy suggesting that children with LI present multiple information processing problems related to both data-driven processing problems and conceptually driven processing problems.

Figure 1 depicts a simple representation of the relationships between data-driven and conceptually driven processing. At the center of the figure is working memory, which we view as a system of encoding, storage, access, and retrieval processes that are used to keep information active at any given moment (Gillam, 1997; Gillam & Bedore, 2000). As it pertains to therapy, working
memory processes would be involved in the child’s ability to remember what he just said, to remember a clinician’s growth-relevant recast, to realize the two utterances are different, and to store pertinent information about the clinician’s example so that it can become part of the child’s own language system. With respect to phonological awareness, working memory processes would be involved in holding a word such as \(/b\alpha/\) in mind long enough to determine that it is comprised of the sounds \(/b/, /\alpha/,\) and \(/\lambda/\).

Information gets into working memory in two principle ways. Data-driven processing (also referred to as bottom-up processing) concerns the way auditory and visual information is received. In data-driven processing, attention and perception systems deal with information before the mind makes complete sense of it. Basic attention and perception problems can place constraints on the auditory and visual data that are available to form mental representations of experiences. Conceptually driven processing (also referred to as top-down processing) concerns the way higher-order thinking influences performance. In conceptually driven processing, learners access mental models to create expectancies for what they will be likely to see and hear. These expectancies influence what is attended to, perceived, and remembered. We believe the processes underlying the creation of mental models are the same processes that guide strategic planning and action in higher level learning contexts. Most of the time, prior knowledge (conceptually driven processing) and moment-by-moment attention and perception (data-driven processing) are simultaneously active in interpreting and responding to experience.

We also depict a Central Executive process, which acts with the learner’s motivation and goals to allocate and coordinate mental actions. A Central Executive process is needed in order to determine what cognitive resources are needed to complete a task, to apply those resources in some degree, and to monitor the outcomes to determine whether other resources or a change in strategy are necessary. For example, children in a classroom are surrounded by numerous information sources to attend to. They may focus their mental energies on children talking around them, on birds and trees outside, at posters on the walls, on the clock, or on the teacher. From moment to moment, children’s central executive functions process all incoming information and direct their thinking toward one or more of these sources of information.
Children with LI have subtle problems with the way they orient to auditory and visual information (a sensory process). They also present difficulties with the way they mentally represent auditory and visual information once it's perceived (a cognitive process). This combination of data-driven and conceptually driven processing problems creates a condition in which children with LI may be unusually sensitive to increasing task demands. Data-driven processing and conceptually driven processing are interactive. Therefore, limitations at one level can affect processing at another level. Children with LI may be able to perform most perceptual, linguistic, or cognitive tasks under optimum conditions. However, their performance may deteriorate rapidly whenever the task is changed so that faster online processing and/or multiple mental steps are required. As tasks increase in difficulty, these children reach performance limitations sooner than their age-matched peers. We refer to this as a threshold effect, and we believe it can result from subtle difficulties throughout the information processing system.

**DATA-DRIVEN PROCESSING**

**Limitations in attention**

Attention involves at least three mechanisms: automatic activation, orientation, and focus (Cowan, 1995). Cowan showed that auditory and visual information can automatically activate populations of neurons within specific cortical centers without conscious awareness. When information is novel or significant, individuals orient to it in ways that increase their level of awareness, making them more sensitive to additional stimulation from the same source. Orientation of attention to a stimulus source also enables a neural model (a particular pattern of nerve cell firing) to be formed, which activates relevant semantic knowledge. This neural model helps individuals focus their activated knowledge in heightened states of readiness until mental processing resources are needed for comprehending and responding.

One way researchers study automatic activation and orientation of attention is by recording neuroelectric activity of the brain. One type of neural activity that is specific to auditory stimuli is called an auditory-evoked potential (AEP). AEP studies suggest that children with LI have automatic activation processes that are as fast as those of typically achieving, age-matched peers (Akshoomoff, Courchesne, Yeung-Courchesne, & Costello, 1989; Roncagliolo, Benitez, & Perez, 1994). However, these studies have only used acoustically simple signals (e.g., sine waves). Children with LI may not orient their attention to more complex auditory stimuli as quickly as their nonimpaired peers or even their language-matched peers (Montgomery, this issue).

An interesting phenomenon occurs after individuals orient to information. As a sound is repeated over and over, attention fades. The sound pattern is not novel or significant, so it leaves the focus of attention. This is called habituation of attention. For example, consider how difficult it is to continue to focus on the message being expressed by a speaker with a monotonous voice. As you habituate to the monotonous speech pattern, you are likely to refocus or shift your attention to other thoughts. However, a sudden change in the stimulus causes your attention to orient to it. Therefore, researchers can
study orientation of attention by calculating the difference between the AEPs for a standard repeated stimulus and the AEPs when the sound is changed suddenly. This type of study is often referred to as the mismatch-negativity (MMN) paradigm.

Marler and his colleagues (Marler, 2000; Marler, Champlin, and Gillam; 2001b) conducted an MMN study on school-age children with LI and their age-matched peers. The children listened to pure tones presented during or immediately after a masking sound. Children with LI had AEPs that were both delayed and reduced in magnitude. These results suggest slowed orientation of attention to complex auditory information.

Riddle (1992) used a behavioral paradigm to study how well children with LI focus attention on a new sound. She asked preschoolers with LI and their age-matched controls to identify pictures of objects having the same name (e.g., two different-looking shoes). A buzzer sounded during some of the picture identification trials. The children's task was to press a button as soon as they heard the buzzer. Although the children with LI were highly accurate on the picture task, their responses to the buzzer were slower in comparison to the responses by the age-matched controls. Thus, children with LI had problems related to shifting the focus of attention.

Gillam, Cowan, and Day (1995) used a suffix effect procedure to study the relationship between orienting functions of attention and working memory in children with LI. Children listened to lists of numbers and then repeated the numbers verbally or wrote them down. For some trials, the last number they heard was followed by a final nonword item /snok/, which is usually referred to as a suffix. Children were told this might happen, and they were encouraged not to attend to the suffix item when they heard it. Even though participants were told to expect the item and to ignore it, the suffix had an unusually detrimental effect on memory for children with LI. This may have happened because their attention was shifted to the suffix more readily, suggesting they had difficulties sustaining attention on the parts of the stimulus that mattered the most. Also, children with LI lost unusual amounts of information from memory when irrelevant information was presented. As the demands of the task increased (children had to remember a series of numbers even though there was an irrelevant sound), their performance decreased much more than the nonimpaired children's performance.

Most models of attention suggest that some information is automatically extracted from each incoming stimulus regardless of the amount of overt focus directed toward the stimuli. Although early automatic activation appears to be as fast in children with LI when they are asked to process simple tones, but even with simple sounds, the magnitude of their brain activity is reduced. Children with LI also appear to have slowed attention orientation. Even after their attention is oriented, children with LI may exhibit a limited capacity for sustaining their focus. When focus is lost, it may be difficult for children with LI to refocus on the mental models they had already established.

Whether children with LI have a diminished attention orientation mechanism, a limited capacity for sustaining the focus of attention, or a limited capacity for returning to a previous focus, limitations in attention processes related to orientation and focus certainly could contribute to language learn-
ing difficulties. Attentional differences in young children could impact language learning through such overt mechanisms as difficulty establishing joint reference of attention with caregivers or confusion regarding conversational turn-taking routines and topic maintenance. In classroom situations, children who have difficulty orienting, focusing, and refocusing would have less information at their disposal for building long-term memories than children who oriented their attention quickly and were able to focus the mental energies for long periods of time.

**Limitations in auditory perception**

One of the oldest and widely studied hypotheses of language impairment is that children with LI have auditory perception difficulties that interfere with language development. For example, Tallal and colleagues (1985, 1997, 2000) have suggested that children with LI have unusual difficulties recognizing and sequencing rapidly presented auditory information. Studdert-Kennedy and his colleagues (Mody, Studdert-Kennedy, & Brady, 1997; Studdert-Kennedy & Mody, 1995) have suggested that children with LI might have more difficulty with frequency and amplitude perception than they have with the perception of temporal aspects of sound.

Elliott, Hammer, and Scholl (1989) and Elliott and Hammer (1993) used an auditory discrimination task to determine the smallest acoustic differences among phonemic stimuli that could be discerned by children with LI and their age-matched normal controls. Subjects were asked to judge whether consonant-vowel (CV) stimuli that varied in voice onset time from 0 to 35 ms in 5-ms steps were the same or different. In comparison to the age-matched controls, children in the LI group required greater differences between the two syllable presentations with respect to voice-onset-time in order to determine whether the syllables were different from each other. Elliott and her colleagues hypothesized that fine-grained auditory discrimination may be related to their ability to learn language. Even if that is true, factor analysis revealed that auditory discrimination measures accounted for only 27% of the variance in language ability in six- and seven-year-old children with LI, and only 16% of the variance in the language abilities of the age-matched controls.

Wright, Lombardino, King, Puranik, Leonard, & Merzenich (1997) and Marler, Champlin, & Gillam (2001a) have used backward masking tasks to measure children's auditory perception abilities. In backward masking a tone occurs just before a masking sound. People with auditory temporal processing problems often have difficulty distinguishing the signal apart from the masker when they are presented very close together in time. However, they can compensate for this weakness when the signal is presented at a suitably intense level. Therefore, elevated signal thresholds in backward masking conditions are thought to reflect difficulties with auditory temporal processing. Like Wright et al. (1997), Marler et al. (2001a) found that children with LI had significantly higher (poorer) signal thresholds than their age-matched peers in the backward masking condition. These findings suggest that some children with LI have auditory temporal processing deficits.

Attention and perception are closely linked. Helzer, Champlin, and Gillam
(1996) measured children’s ability to perceive non-speech stimuli within three different masking conditions and two different signal frequencies. Eight children with specific language impairment (LI) and eight, nonimpaired, age-matched peers completed a masking period pattern paradigm in which a signal (500 or 200 Hz) was measured with no competing noise, with continuous competing noise, with a short (40ms) gap in the noise, or with a long (64ms) gap in the noise. Across frequencies and gap sizes, thresholds for children with LI were quite similar to that of their nonimpaired, age-matched controls. But, children with LI required significantly more trials to achieve the same threshold levels as their age-matched peers. The results of the trials to criteria measure suggest that attention, or lack thereof, may play an important role in perceptual functioning.

Some speech discrimination tasks are not difficult for children with LI. Sussman (1993) asked children with and without LI to listen to a series of syllables whose starting formant frequencies were on a continuum from /ba/ to /da/. Children touched an “X” when they detected a change in the syllables. Next, children performed an identification task in which they listened to the syllables again. This time, they were to touch a “B” if they thought the syllable was /ba/ and a “D” if they thought the syllable was /da/. Sussman found that children with LI were as adept as their language and age-matched controls at discriminating changes in the CV syllables. However, these children presented unusual difficulties with the identification task using the same stimuli. Sussman concluded that children with LI have trouble forming phonological representations of acoustic information, a topic we will consider in greater detail in the next section.

Evidence from a variety of studies suggests that children with LI have limitations in data-driven processing related to attention and perception, but these problems are related to the complexity of the task and/or the complexity of the stimuli. Therefore, children with language impairments may learn single words reasonably well when they orient their attention, focus their mental energies on the task at hand, and receive clear auditory input. However, if they happen to orient their attention to nonrelevant stimuli in the environment, fail to focus their mental energies on the learning task long enough to create stable mental representations, or do not perceive the component sounds clearly, they will have a limited ability to remember new words or sentences. Similarly, words, morphemes, or sentence structures that are embedded in a rapidly presented speech stream or complex sentences will also be difficult for children with language impairments to acquire.

CONCEPTUALLY DRIVEN PROCESSING

Limitations in the adequacy of phonological representations

Studies of the role of phonological representation in working memory may help us understand the nature of capacity limitations in children with LI. Gathercole and Baddeley (1990; 1995) characterize language acquisition and processing as part of a working memory system consisting of separate mechanisms for verbal and visual information processing. Visual information is thought to be retained via the visuospatial
sketchpad, while verbal information is processed in a phonological loop comprised of a phonological short-term store where speech input is encoded and a subvocal articulatory rehearsal process that serves to refresh speech material. According to Gathercole and Baddeley's working memory deficit hypothesis, children with language impairment have a reduced verbal working memory storage capacity. Further, these authors believe that phonological processing skills such as perception, encoding, or rehearsal may contribute to children's language deficits (Gathercole & Baddeley, 1990).

Children who have difficulties encoding phonological information should demonstrate unusual problems processing and remembering nonmeaningful word-like stimuli. Nonword repetition tasks have been used as measures of phonological working memory on the premise that recall of this type of stimuli should be independent of lexical knowledge and, therefore, performance should reveal phonological processing efficiency rather than measuring vocabulary or semantic contributions to word retention. There is a consistently powerful and pervasive finding that children with language impairment recall less nonword information than their normally achieving peers (Kamhi, Catts, Mauer, Apel, & et al., 1988), particularly when the task stimuli become polysyllabic (Edwards & Lahey, 1998; Montgomery, 1996).

Edwards and Lahey (1998) argued for caution in interpreting accuracy on nonword repetition tasks as a measure of phonological capacity. They proposed that reduced accuracy on these tasks could be indicative of aspects of processing requiring effort that exceeds processing capacity limitations.

Poor performance may reflect effort rather than an inherently constrained working memory capacity or a specific phonological representation deficit. They stated that "it is not that children with specific language impairment cannot form accurate phonological representations; rather it may be that some children with specific language impairment must work harder to form these representations than their peers, and in doing so they overload their system" (p. 305). Edwards and Lahey (1998) suggested that "further research is also needed to examine how processing load might interact with the nature of phonological representations" (p. 304).

Gillam, Cowan, and Marler (1998) used a modality effect study to investigate processing load and phonological representation. These authors measured the digit recall of two groups of subjects (children with LI and their age-matched controls) in six conditions that counterbalanced three types of stimuli (auditory, visual, and audiovisual) with two types of responses (speaking or pointing). Sixteen children with LI between the ages of 9 and 12 and 16 age-matched children recalled lists of digits that were presented in auditory, visual, and audiovisual (mixed) presentation modes.

Gillam et al. (1998) found group differences between input and output modalities. The children in the LI group showed especially poor performance when a visual stimulus was combined with a pointing response. Children with LI had reasonably good recall when auditory stimuli were paired with spoken responses, but they had unusual difficulties with recall when visual stimuli were paired with pointing responses. Thus, these children had trouble converting visual input into phonological forms for re-
hearsal and then back into nonspeech (pointing) responses.

For children with LI, the increased mental processing required for recoding a phonological representation into a visual form and then back into a phonological form interfered with their ability to retain the initial phonological codes. As a result of the extra mental processing that was required, their phonological representations might have decayed such that they were not available for recall processes. It is also likely that children with LI did not have the mental capacities that were needed to quickly rebuild their decaying representations. Thus, they were more likely to “forget” the visually presented digits when a pointing response was required than when a speaking response was required.

If children with LI do, in fact, have difficulties with phonological coding, what might be the nature of such a deficit? First, as suggested by Gathercole & Baddeley (1990), children with LI may be limited in their capacity to form adequate phonological codes. That is, they may create incomplete or “fuzzy” phonological representations of spoken or written words. They may not consistently “hear” all of the critical phonetic cues necessary to differentiate one sound from another. Or, even if they “hear” important cues in the auditory signal, they may not mentally mark those cues with enough regularity to highlight them or remember them to the extent needed for building accurate and complete phonological representations. As a result, their internalized phonemic boundaries may be too narrow or broad relative to the phonemic targets of the population at large, resulting in an inability to adequately recognize or generate meaningful phonological distinctions at the word level. If this were the case, the young child with LI might have difficulty discerning “pat the goat” from “bat the coat” or “pat the coat.” If these indistinct phonological boundaries were not resolved before the child was expected to begin to read, they might experience problems accurately associating phonemes with graphemes.

A second explanation might be that phonological coding deficiencies may involve limitations in the capacity to retain adequate representations across multiple processing conversions. Such phonological coding problems could be a consequence of phonologically specific processes or of general difficulties with mental processing and retention of any type of information, including phonological representations. The inability to retain phonological representations during processing efforts could result in decreased processing efficiency, which could impede the ability to establish meaningful phonologic units. This could, in turn, detract from the ability to establish early morphemes and a stable semantic network.

Limitations in mental models

We noted earlier that children create mental representations of semantic knowledge after they orient to a stimulus. Individuals tend to form complex associative networks of associations between multiple bits of knowledge. These networks are sometimes referred to as mental models. A research paradigm known as the “fan effect” has appealing properties as a measure of the sufficiency of mental models. In this paradigm, participants memorize a series of novel training sentences. Some of the training sentences have the same subjects, some have the same verb phrases, and some sentences have nothing in common with any of
the other sentences. After they memorize the sentences, they complete a sentence recognition task. The typical finding with adults is that sentences that share the most information yield the longest verification times (Cantor & Engle, 1993), suggesting that sentences with shared information are represented in a single mental model.

Gillam and Ellis Weismer (1997) administered a fan effect protocol to 16 school-age children with LI, a group of normally-achieving, age-matched peers, and a group of memory-matched peers who had similar scores on Gaulin and Campbell’s (1994) competing language processing task. All the children memorized twelve target sentences that varied according to the amount of overlapping and nonoverlapping information. Some of the sentences shared no information (e.g., “Barbie ripped her pants.” and “Batman drank some water.”), some sentences shared subjects (e.g., “Superman turned the handle.” and “Superman shut his eyes.”), and some sentences shared verb phrases (e.g., “Pocahontus threw the ball.” and “Belle threw the ball.”). Later, they listened to test sentences and were asked whether or not they had studied each one. Most of the sentences were the ones they studied, but some were foils like, “Barbie threw the ball.”

The students in the study, including those with LI, successfully learned the 12 sentences with minimal errors. Children with LI were poorer than their age-matched peers but similar to their memory-matched peers in verifying whether a sentence was one they actually studied. Therefore, children with LI performed the verification recognition task at a level that was consistent with their working memory ability. However, children in the LI group responded significantly slower than children in both the age-matched and memory-matched groups to all types of items, not just to the fan items. This finding suggests that children with LI created mental models that contained fewer associations than the mental models produced by their peers.

**Limitations in processing expository texts**

Classroom lectures and discussions are among teachers’ primary instruction tools. How well children and adolescents with LI recall and comprehend material from instruction is critical to their school success. Wynn-Dancy (2001) designed a study to investigate the effects that assistance with data-driven processing (slowed presentation rate) and conceptually driven processing (activation of prior knowledge) would have on working memory for expository texts. Adolescents with LI heard texts presented with normal and slow speaking rates. Before some texts were presented, students completed tasks to activate background knowledge that was related to the topics of the history lessons.

The participants were ten adolescents between the ages of 13 and 15 years, diagnosed with LI, ten reading-matched controls, and nine age-matched controls. The students watched four videotaped lessons about the great trading empires of Africa. After the lessons, students completed a sentence recognition task and retold as much of the lessons as they could remember.

All the participants had greater sentence recognition accuracy when the texts were presented at a slow presentation rate, and activation of prior knowledge did not aid sentence recognition. With respect to text recall, adolescents with LI remembered fewer propositions from the history lessons than their reading and age-matched peers.
All the participants generally had the best recall when activation of prior knowledge was paired with slowed presentation rate. These results suggest that while adolescents with LI may have sufficient processing ability for recognition of expository text, they generally know less about the topic at hand, and their deficiencies in working memory limit the multiple mental operations required to develop organizational structures that support efficient storage, retrieval, and reporting from long-term memory (Wynn-Dancy & Gillam, 2001). Limitations in these mental operations would also interfere with strategic planning and self-regulated learning in formal educational contexts.

**Limitations in reading**

Recently, Gillam and Carlile (1997) analyzed the oral reading and story retelling of school-age children with LI who were between the ages of eight and eleven years. They matched students with LI to younger, normally achieving students according to their single word decoding skills. All the children were asked to read and retell stories that were approximately one grade level above their reading level. Despite that fact that the two groups were matched on single word identification skills, the children with LI had a larger percentage of word identification errors and a smaller percentage of self-corrections. When we compared the word identification errors (miscues) of both groups, we found that the younger, normally achieving children’s miscues were more similar to the printed words, and their miscues were less likely to cause sentences to be ungrammatical. Because the single word decoding of the two groups was identical, it appeared that the demands of reading whole stories had an unusually large negative effect on the decoding skills of the children with LI. That is, it was difficult for these children to build textual mental models that supported data-driven processes related to word identification.

The main purpose of our study, however, was to look carefully at the way children with and without LI coordinated graphophonemic, syntactic, semantic, and pragmatic cues in printed text. There were many instances in which children with LI used a single cue system to guide their reading. In comparison, this rarely occurred for the decoding-matched controls who were much more likely to integrate information from multiple cue systems when they were unsure of a word. Students with LI had the basic graphophonemic knowledge and sound blending abilities to support decoding. Their primary problem was that they experienced far greater difficulty integrating print cues than younger students with similar levels of word decoding skills. Once again, the evidence suggests that these children had unusual difficulty dealing with complex stimuli. In this case, children with LI were not adept at creating sentence and text-level mental models and using those models to support word recognition. It may be argued, as well, that these children were not acting strategically with respect to their reading. That is, they were focusing their mental efforts on word identification processes using phonological cues and excluding other semantic and syntactic cues that could have aided their understanding of the text.

**CENTRAL EXECUTIVE FUNCTIONS**

There are other aspects of working memory besides phonological representation that may play a critical role in the development of language abilities and subsequent impairments. As we noted earlier, Baddeley
and Hitch (1974), proposed a model of memory in which there are two slave systems that are highly specialized for the processing and temporary storage of material within auditory and verbal domains. Verbally coded information is maintained by the phonological loop, while information that is spatial or visual is processed by the visuospatial sketchpad. The central executive component coordinates the flow of information within working memory by encoding and retrieving information from the visual and auditory slave systems. Further, it activates and retrieves information from long term memory, and regulates the overall processing and storage of information. The central executive component of working memory is thought to be responsible for selective attention, coordination of performance on two or more separate tasks, and inhibition of disruptive effects of competing or irrelevant stimuli (Baddeley, 1996).

As such central executive mechanisms would appear to be the linchpin of processing between sensory stimuli and higher order cognitive processes and could, in fact, prove to be a critical bottleneck in the information processing systems of children with language impairment.

While the phonological loop component of working memory has been extensively studied, the central executive component has not. Hoffman (2000) designed a study to explore the interactions among various information processing factors, including central executive functions. The central executive function of coordinating dual processing efforts within and across domains was examined. Children were asked to repeat a series of visually presented digits or to point to the locations of a series of x’s on grids. Sometimes, they were also asked to complete secondary tasks requiring them to identifying the color of the stimuli as they were presented using either a naming or pointing response. There were six conditions that crossed primary task (verbal or spatial) with secondary task (none, verbal, or spatial) under two rates of presentation (fast or slow). Forty-eight children (24 with LI and 24 with normal language skills) between the ages of 8:0 and 10:11 years of age participated in the study. All subjects demonstrated normal hearing sensitivity, no significant disturbances in emotional or environmental status, and nonverbal intelligence quotients of 85 or higher. The children in the LI group demonstrated receptive and/or expressive language deficits that resulted in composite standard scores of at least 1.5 standard deviations below the mean for their age.

The primary findings were that children with LI had poorer memory for with spatial information (the placement of x’s on a grid) than for verbal information (digits), especially when the primary and secondary tasks were from different domains (one was verbal and the other was spatial). Normally developing children actually performed better under these circumstances. Children with LI did not appear to benefit from the opportunity to disperse processing across modalities to the same extent that their age-matched peers did. This inability to effectively disperse processing across verbal and spatial domains seemed to create a cumulative effect that resulted in inefficient and ineffective information processing for the LI group, particularly in conditions that included a spatial secondary task. This susceptibility to nonspecific domain interference (difficulty processing secondary task information that was presented in the opposite domain of that of the primary tasks) suggested group differences in central executive functions.
The potential role of central executive function in language development can readily be hypothesized as follows. During the process of establishing semantic stores in long-term memory, all incoming stimuli could be conceived of as a continual sensory puzzle stream that requires analysis, coordination, and interpretation. Information that is spatial and visual in nature is processed by the visuo-spatial sketchpad component of working memory, while verbal/auditory information is processed by the phonological loop. The central executive component regulates the flow of information processing between these two systems. At the same time, it supports the development of meaning by coordinating selective attention (which would also support the establishment of joint reference between child and caregiver) and the storage of information in long-term memory.

Over time, exposure to repetitive combinations of sensory stimuli would establish sensory patterns that would be recognized by the central executive as being important due to their consistency and frequency. In response, the central executive could regulate the long-term storage of this information to support the development of coherent phonological or imagistic representations in long-term memory. The continual coordination of multidomain sensory information would lead to the creation of representations of meaningfulness in long-term memory. These representations form the semantic network that is the basis of language development. Therefore, adequate central executive function in working memory may be critical to the development of language in young children. In addition, the basic functions of the central executive component would appear to provide the bedrock foundation for the development of higher order cognitive skills involved in attending selectively, inhibiting actions, restraining and delaying responses, planning, and organizing information. Comprehension difficulties, a fragmented semantic network, difficulty participating in conversations, an inability to interpret abstract or figurative language or syntactic limitations could potentially result from disturbances to the central executive function of working memory.

Summary

We have reviewed evidence concerning processing limitations in attention, auditory perception, the adequacy of phonological representations, central executive functions, expository text processing, and reading. Basic attention and perception problems can limit mental representations of visual and auditory experiences before they are used in thinking. Once they are formed, learners use conceptual models to create expectancies for what they will be likely to see and hear. These expectancies influence what is attended to, perceived, and remembered. Regardless of what the primary or secondary limitation might be, it is likely that the language learning abilities of most children with LI are simultaneously constrained by multiple factors that affect information processing. Findings like these lead us to question how “specific” language impairments really are. Next, we turn our attention to the clinical implications of information processing problems.

CLINICAL IMPLICATIONS

We have shown that data-driven and conceptually driven processing contribute to language development and language disorders in children. Clinicians may wish to
attend to these two processing strategies in assessment and intervention. Gillam and Hoffman (2001) presented a framework for assessment that was designed to provide clinicians with basic information about psychological structures underlying language development (attention, perception, memory, and reasoning), children's use of language structures and functions in natural situations, and the level of their engagement in activities that involve communication. In this system clinicians observe language and psychological functions as they watch children respond to various types of directions, answer questions, and engage in social play. We are particularly interested in gaining information about the number of mental schemes children are able to combine together in these situations, the speed at which they process information, and the strategies they use in learning.

Perhaps the most ecologically valid way to assess the psychological functions that support language development is through a process known as dynamic assessment. As we will explain further in the next section, dynamic assessment is a test, teach, retest procedure in which clinicians observe children's information processing and language skills while they are learning a new skill.

**Dynamic assessment**

Dynamic assessment enables speech-language pathologists (SLPs) to observe psychological and linguistic functions and activities as children are engaged in language learning. Dynamic assessment usually begins with a testing phase in which the examiner administers a pre-test. During a teaching phase, the examiner teaches one or two lessons that are designed to impact the child's performance on the pre-test measure. Then, in the post-test phase, examiners readminister the pre-test.

Dynamic Assessment yields data about language learning functions and language learning potential. Children's responses to the teaching phase of dynamic assessment provide important data about attention, perception, memory, and central executive functions during language learning. The amount and type of changes that result from intervention are an indication of the child's language learning potential.

For example, Gillam, Peña, and Miller (1999) and Miller, Gillam, and Peña (2000) describe an approach for the dynamic assessment of narratives. Clinicians begin by having children create stories as they look at wordless picture books. Then clinicians mediate some aspect of story telling in two separate intervention sessions. After the mediation sessions, clinicians ask children to create a story about a second wordless picture book that contains the same number of pictures and the same story structure as the book that was used for the pretest.

Based on their analysis of the pretest story, clinicians select the goals for two mediation sessions. Clinicians should target aspects of narration that the child has some knowledge of in one of our mediation sessions. For example, if a child's story contained an incomplete episode, the clinician might decide to focus on teaching a missing element that would be required for a basic episode (initiating event, attempt, or consequence). During the second mediation session, clinicians should target an aspect of narration for which the child demonstrated little or no knowledge. For example, the clinician might focus on setting information if the child did not include any information about where the story occurred.
Clinicians administer a post-test after the two mediation sessions. Clinicians should consider the kinds of changes the child made, how much effort was required to accomplish these changes, and the type of the change that was observed. More specifically, clinicians should ask questions such as:

- Was the child able to focus his attention on the critical aspects of the lesson?
- Did the child shift the focus of attention at appropriate times?
- Did the child understand your questions and explanations?
- Did the child relate past experiences to new information that was presented?
- Was the child able to construct inferences?
- Was the child able to generalize what he learned to new stories?
- Was the child able to form a more complete and/or more coherent story after mediation?
- How hard did the SLP have to work in order for the child to make positive changes?
- Was the child’s learning quick and efficient or slow and labored?

The answers to these questions are useful for determining whether a child’s underlying information processing abilities are sufficient to support language learning. Children who make rapid changes and who are highly responsive to the mediation sessions rarely have information processing problems or language impairments. When provided with instruction that focuses their attention on the necessary elements of narratives, good language learners are able to quickly and efficiently make changes. On the other hand, children who need continued support and who have a difficult time making even small changes in their verbal skills, are very likely to have language impairment. These children typically demonstrate low responsiveness to instruction, require high examiner effort, and make few pre- to post-test changes.

As part of a complete assessment, clinicians should also assess children’s participation in everyday activities, their level of involvement in social, educational, and prevocational experiences, and environmental factors that hinder or facilitate their functioning and participation. These areas are best assessed by interviewing children, parents, and teachers and by observing children in their natural environments.

**Intervention suggestions**

Because language and information processing are dynamically related, good language intervention is also good information processing intervention. We believe the primary focus of language intervention should concern form, meaning, and use interactions in pragmatically relevant contexts. For preschoolers, clinicians often use facilitative interactions that include imitation, modeling, focused stimulation (including milieu teaching), and growth-relevant recasts (see Leonard, 1998 for a summary of these techniques). These types of facilitative interactions can be used to teach a variety of intervention targets. For school-age children, many clinicians use book discussions as the primary context for intervention because this kind of talk commonly occurs in elementary-school classrooms. In this approach, activities that facilitate semantics, syntax, morphology, narration, and phonological awareness are centered on a common theme.
Intervention that combines direct instruction and strategy instruction holds considerable promise for intervention within an information processing framework. In addition, both direct instruction and strategy instruction can fit comfortably into the test, teach, retest procedures of dynamic assessment. This model of intervention holds promise as a “good fit” for remediating language problems that may be rooted in both data-driven and conceptually driven processing deficits.

Direct instruction is an intervention approach that provides clear skill instruction within graduated steps with multiple opportunities for learning. A distinctive feature of direct instruction is its focus on subskills, such as letter sounds or linguistic units. Much of the phonological awareness intervention fits the description of direct instruction. The goal is to fine-tune a subskill, hopefully to the level of automaticity, so that students’ processing in working memory can be freed for higher level thinking. When word recognition is automatic, students can more rapidly ascend to the business of meaning-making during text processing. Considering that a goal in direct instruction is automatic processing of a subskill, these approaches are often used to support data-driven processing. For example, Fast ForWord (Scientific Learning Corporation, 1997) is an example of a direct instruction approach that specifically targets attention and perception processes.

On the other hand, strategy instruction is more global. It is a “big picture” type of intervention. Though it may utilize a graduated sequence, the ultimate goal is the development of text macrostructures and metalinguistic understanding that enable students to communicate effectively in oral and written modalities. At the heart of strategy instruction is an emphasis on metacognition: understanding why a strategy is needed, selecting a strategy, and determining whether a selected strategy is successful or unsuccessful. Successful intervention to improve conceptually driven (top-down) language processing must stress connecting prior knowledge with new knowledge for the purpose of facilitating effective information processing in expository, narrative, or conversational discourse.

There are a number of techniques that clinicians can use to facilitate information processing while incorporating either direct instruction or strategy instruction approaches in therapy.

Help students focus their attention

Tell students what the purpose of the lesson is and why it is important. Then, as the lesson is continuing, ask them to explain what they are learning, why they are learning it, and how they will remember to use their new knowledge.

Talk Slower

This seems like such a simple-minded suggestion. Yet, it may be one of the most powerful tools teachers, parents, and clinicians have at their disposal. Children with LI need more time to process information, and they get that time when SLPs simply speak more slowly and deliberately, with emphasis on the critical information.

Build better knowledge bases

Both conceptually driven and data-driven factors intertwine in text processing. Wynn-Dancy and Gillam (2001) found that activation of prior knowledge produced better recall. SLPs should talk to children about
what they know that relates to the topics of lessons they will be studying. Then, they should add to this knowledge base in small steps, with frequent opportunities for children to rephrase their old knowledge and explain how it relates to new knowledge.

**Build mental maps**

SLPs should create schematic maps with students. As new information is being acquired, the SLP and the student work together to write key words for the concepts and link the key words together with lines. Schematic representations can help children visualize and represent ties between new and old knowledge.

**Help with cue integration**

Students with LI who present reading difficulties should profit from remediation efforts that focus on the integration of graphophonemic, syntactic, and semantic-pragmatic cues. Group mini-lessons that focus on specific kinds of cue integration problems have been helpful for demonstrating how to attend to multiple cue systems. The basic procedure is rather simple. SLPs create overheads of “cloze” sentences that are “gated,” which means that each sentence provides successively more information than the sentence before it. All the sentences are covered except the first one. As each sentence is uncovered in succession, students brainstorm answers that fit the cues that are provided. All the words that fit the available cue constraints are written on the chalkboard. After each new sentence, the group discusses which words no longer fit the cues and the reasons why these words are no longer appropriate. When the final sentence is uncovered, the entire group sees what word the author had intended. Sentences can be found in student’s reading assignments.

For example, students who present patterns of miscue substitutions that are graphophonemically dissimilar from printed words, need extra practice in integrating sequences of graphophonemic cues to fit minimal semantic and syntactic constraints. SLPs can create a set of overheads like the following.

a. The girl saw the __.

b. The girl saw the c __.

c. The girl saw the co.

d. The girl saw the com.

e. The girl saw the comb.

To demonstrate the integration of graphophonemic and semantic-pragmatic cues, create sentences like the following.

a. It was cold outside so I put on my __.

b. It was cold outside so I put on my __.

It made my head warm.

c. It was cold outside so I put on my c. It made my head warm.

d. It was cold outside so I put on my cap.

It made my head warm.

To demonstrate the integration of graphophonemic, semantic-pragmatic, and syntactic cues, create sets of sentences like:

a. Our whole class went on a field trip. __ got lost. When we found __, __ said, “Where have you guys been all this time?”

b. Our whole class went on a field trip. S got lost. When we found h, s said, “Where have you guys been all this time?”

c. Our whole class went on a field trip. Sus got lost. When we found he, sh said, “Where have you guys been all this time?”

d. Our whole class went on a field trip. Susan got lost. When we found her,
she said, “Where have you guys been all this time?”

Use mediated teaching

Miller, Gillam, and Peña (2000) have outlined procedures for applying the principles of dynamic assessment to the intervention of children’s narratives. The steps involved in this approach are presented in Table 1. The principles of mediated teaching could be applied to a variety of intervention targets.

Research suggests that many children with specific language impairment have problems in the areas of attention, speech perception, phonological representation, central executive functions, and/or general processing capacity. We believe there are dynamic relationships between these information processing functions and language learning capabilities. Because language development is the outcome of information processing, information processing difficulties underlie language impairment.

Clinicians should assess information processing mechanisms that contribute to language learning. There are many standardized tests that claim to evaluate one or more information processing functions. Most of them have questionable validity and reliability. It is our opinion that the best way to assess the information processing abilities that affect language development is to carefully observe children as they are in the act of learning language. We summarized one approach, known as dynamic assessment, in which examiners test a language skill, teach aspects of language that children do not know, and then retest to see how much the child profited from instruction.

Information processing is essential for language, and the development of more complex language increases the efficiency and capacity of information processing. As such, much of what happens in language intervention is also information processing intervention. We have argued that the most effective language intervention is performed in contexts that are as similar as possible to children’s everyday speaking experiences. However, at times, it may be wise for clinicians to focus on particular aspects of information processing within the larger context of pragmatically relevant therapy.

<table>
<thead>
<tr>
<th>Technique</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intention to teach</td>
<td>Tell students what the goal of the lesson is.</td>
</tr>
<tr>
<td>Meaning</td>
<td>Discuss with students how and why the goal is important.</td>
</tr>
<tr>
<td>Example</td>
<td>Provide concrete demonstrations and strategies.</td>
</tr>
<tr>
<td>Transcendence</td>
<td>Promote metacognitive awareness by discussing alternative strategies and answers</td>
</tr>
<tr>
<td>Transfer</td>
<td>Provide opportunities for children to generalize what they have learned to new contexts or problems.</td>
</tr>
<tr>
<td>Self-evaluation</td>
<td>What did you learn? How did you learn it?</td>
</tr>
<tr>
<td>Planning</td>
<td>Discuss how and when students will use what they have learned</td>
</tr>
</tbody>
</table>
REFERENCES


assessment and intervention of children's narratives. Austin, TX: PRO-ED.