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# Preface

In the past 10 to 15 years there has been an explosion of research on neurologic development, the neurofunction underlying language and learning, and the neurologic basis of developmental disorders. One of the factors contributing to this rapid increase in information is the availability of noninvasive neurofunctional and neuroimaging techniques that can be used with children and adults with developmental disorders. In addition, cognitive scientists have contributed large numbers of behavioral studies that have led to greater understanding of information processing and learning in both typical and atypical populations.

Related to the advances in cognitive science and neuroscience is a growing interest in the development of teaching strategies that are based on an understanding of the brain-behavior relationship. This is an area of interest to speech-language pathologists and special educators who work with children with developmental language disorders. Unfortunately, most of the relevant research is in highly specialized publications that are not readily available outside research and academic settings. Cognitive science or neuroscience textbooks that offer an integration of published research are not focused on developmental language disorders, nor are they written from a clinical perspective. I wrote this book to fill that gap, to make recent cognitive science and neuroscience research accessible so that it could be integrated into clinical and educational practice with children with developmental language disorders.

This book was written for graduate students, practicing speech-language pathologists, and special educators. The information is presented at a level that can be understood by professionals outside the fields of cognitive science and neuroscience. Moreover, this book is written from the perspective of a speech-language pathologist and special educator so that it includes information that is important for a practicing professional. In addition, I have integrated the information and directly applied it to assessment and intervention of children and adolescents with developmental language disorders.

I have had a unique career path that makes it possible for me to translate cognitive science and neuroscience for clinical practitioners and special educators. In my clinical practice as a speech-language pathologist, I specialize in treating pediatric populations, particularly those with challenging communication disorders. The children I have served have had autism, cerebral palsy, mental retardation, fetal alcohol syndrome, specific language impairment, and a variety of genetic conditions including Fragile X, Down syndrome, and Williams syndrome. I have worked with children from birth into adulthood in a variety of clinical settings including the neonatal intensive care unit, inpatient pediatric units, community-based agencies and clinics, public schools, group homes, and university clinics. After 18 years of full-time clinical practice, I returned to school to pursue my doctorate in speech-language pathology. My area of emphasis was pediatric neurogenics with courses in cognitive neuroscience, neurologic development, and the neural basis of pediatric speech and language problems. After obtaining my doctoral degree, I completed a postdoctoral fellowship with Nancy J. Minshew, M.D., a pediatric neurologist and director of the Center for Autism Research at the University of Pittsburgh. During my postdoctoral fellowship, I took additional coursework in neuroimaging and completed a number of neuropsychological research projects in autism. I was then awarded a Research Career Development Award from the National Institute on Deafness and Other Communication Disorders to study the neurocognitive basis of language processing in autism. This award allowed me to complete additional coursework at Carnegie Mellon University in cognitive neuroscience and neuroimaging. I also began to conduct neuroimaging research under the mentorship of Marcel A. Just, Ph.D., D.O., Hebb Professor of Psychology and the Director of the Center for Cognitive Brain Imaging at Carnegie Mellon. I have completed a number of research projects using functional magnetic resonance imaging to study cognitive and linguistic processing in autism. In my current research, I use functional imaging to investigate social, emotional, and language processing in children and adults with autism. I have continued to practice clinically through my work as the Director of the Child Language Program in the Department of Speech-Language Pathology at Duquesne University in Pittsburgh, PA.

This book focuses on what is known about the neurobiological basis of language development, the learning of language, and developmental disorders that affect language learning and use. It takes the perspective that assessment and intervention of children and adolescents with developmental language disorders should incorporate an understanding of the underlying neurofunctional basis of those disorders. The initial chapters present a primer of neuroanatomy and neurophysiology that relates to developmental disorders and neurologic development during the prenatal period. They also cover neurologic development postnatally through childhood and young adulthood including what is currently known about the effects of the environment on brain organization and learning. Chapter 3 provides background information on neurofunctional and neuroimaging techniques for those who may not be familiar with these methods. The following chapters present current research on the neurologic basis of developmental language disorders, dyslexia, autism, and genetic conditions associated with mental retardation (e.g., Down syndrome, Fragile X, and Williams syndrome). The last three chapters focus on the translation of cognitive science and neuroscience concepts and research findings to the design of assessment and intervention for disordered language. I first present basic principles and concepts and then more specific suggestions for early intervention and then for assessment and intervention with older children and adolescents. The suggestions offered in the last chapters are in no way exhaustive but are meant to stimulate the reader's thinking in this area and facilitate the application of the information to clinical practice and teaching.

My position as an academic researcher gives me access to a vast array of published research and the time to read and write that is not generally available to practicing speech-language pathologists and special educators. In writing this book, I hope to be useful to my fellow practitioners, to enhance their clinical practice and teaching as they work every day to make life better for children who live with the challenge of developmental language disorders.

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make learning more challenging. The latter statement should not be interpreted to mean that all children have equal potential for learning language. For all of us, there are biological constraints or limits on the potential of brain development. However, even given these biological limits, learning studies suggest that there is potential for skill acquisition if the appropriate methods are employed. To choose appropriate methods, we must understand more about the brain, how it develops in response to the environment, and how it processes information. We also must understand the biological constraints associated with individual genetic variability and the variability imposed by developmental disorders.

This chapter is the beginning of the process of understanding the brain and how it functions to produce cognition, learning, and language. Ideally, this understanding will result in more thoughtful and directed interventions for children with developmental language disorders.

## BRAIN-BASED MODELS OF DEVELOPMENTAL LANGUAGE DISORDERS

There are many different explanations of language acquisition and related models of developmental language disorders. In this book, the bias is toward what has been referred to as biologically, neurobiologically, or brain-based models (Bates, Thal, Finlay, & Clancey, 2003; Karmiloff & Karmiloff-Smith, 2001) and the related accounts based on information processing models of language and cognition (e.g., Bates & MacWhinney, 1989; MacWhinney, 1987). I have found these approaches to be the most useful guides for both my research and my clinical practice. Other approaches to explaining and describing language acquisition, such as behavioral approaches (based on the work of Skinner, 1957), linguistic approaches (based on the work of Chomsky, 1965), cognitive approaches (based on the work of Piaget, 1954), and social-interaction approaches (based on the work of Vygotsky, 1962) are useful clinical guides for developmental language disorders. Many resources are available on the application of these approaches to the clinical practice of speech-language pathology and the practice of special education. My intention in this book is to make resources available on the neurobiological basis of language and learning. It is intended for practitioners working with children and adults who have language impairments associated with developmental disabilities. This book provides: (1) background information on the development and maturation of the neural systems underlying learning and more specifically, language learning, (2) current understanding of the neurologic basis of language processing based on neurofunctional research, (3) recent research on the neurobiologic basis of learning in developmental disorders associated with problems with language learning, and (4) information on what has been termed *brain-based* assessment and intervention practices as these relate to developmental language disorders.

Brain-based models of language development are rooted in cognitive neuroscience, which is the marriage of cognitive psychology (the study of human memory and learning) and neuroscience (the study of neural development and functioning). Brain-based models of language development therefore, are based on the study of language development in relation to neurologic development. The basic assumption of a brain-based model is that language development cannot fully be understood apart from an understanding of the biological development of the brain. A brain-based approach to developmental language disorders requires both an understanding of normal neurologic development and an understanding of the effects of the atypical neurologic development associated with a particular disorder.

## KEY CONCEPTS OF BRAIN-BASED MODELS OF LANGUAGE DEVELOPMENT

There are a number of key concepts of brain-based models of language development:

1. Whereas language development is based on the genetically controlled unfolding of brain maturation, this maturation occurs in response to environmental input. Language development is influenced by both *genetic* and *environmental* factors.

2. Although language comprehension and production involve *language-specific* brain mechanisms, more general cognitive resources in the brain are also incorporated into the various types of language processes.

3. There are a number of *sensitive periods*, or critical windows of opportunity, during cognitive and linguistic development. These

periods are thought to be associated with key periods of neuronal/brain development. Sensitive periods are times when the brain is ready for learning in the sense that neural mechanisms are available for the processing task. These periods also are times when the brain needs to have input to proceed on an optimal developmental course.

4. Learning is realized as functional and/or structural changes in the brain.
5. The presence of a developmental condition such as autism, Down syndrome, Fragile X, Williams syndrome, dyslexia, or specific language impairment, will interfere with the development of language because it interferes with brain development and alters the way the brain responds to environmental input.

## INFORMATION-PROCESSING MODELS

Models of language learning that are based on cognitive neuroscience may also incorporate information-processing models of learning. Current models of brain function often incorporate concepts of information-processing, frequently using analogies and terminology borrowed from computing. According to information-processing models of language learning, language comprehension occurs as follows:

1. The brain encodes stimuli from the environment. In the case of spoken language, this input is in the form of sound waves. These sound waves are neurally encoded so that the brain can use the input. In the case of written language, the input is orthography, which is neurally encoded through the visual system.
2. The brain recognizes statistical regularities in the input and weighs information so that the most salient information receives more processing attention.
3. The phonological, syntactic, semantic, and pragmatic elements of the message are processed.
4. The meaning of the information is extracted from these elements. The meaning of the message is stored using the brain's memory system.

5. As a human develops, extraction of meaning also includes the retrieval of previously stored information as well as the integration of newly processed information with previously learned and stored information.
6. The processing of language is influenced by nonlinguistic and linguistic contexts within which it occurs. This contextual information may involve other brain regions and require the integration of information within and across brain regions.

Language expression occurs as follows:

1. The speaker/writer conceives of an utterance or idea they want to express.
2. The message is encoded using lexical and grammatical elements.
3. These lexical and grammatical elements are translated into appropriate phonological codes.
4. These phonological codes are translated into articulatory motor sequences in the case of speech and graphomotor sequences in the case of writing.
5. These motor sequences are produced by the motor system, which includes the motor cortex and the cerebellum.
6. In the case of speech, these motor sequences guide the articulatory and vocal systems to produce auditory information. In the case of written language, the motor sequences guide fine motor movements to write or type visual information.
7. Context influences the expression of language, placing particular demands on prosodic and pragmatic variables that require integration of information across regions of the brain.

During the developmental process, the brain uses language input to help organize the cortical networks necessary for learning and using language. As the brain processes more language input, it becomes a more efficient and skilled processor of language. Therefore, language processing requires specific or dedicated language-processing mechanisms, but it also requires more general cognitive mechanisms such as attention and working memory.

## FUNCTION FOLLOWS STRUCTURE

To understand neurologically based models of language development and language disorders, it is essential to understand the brain, how it develops, how it functions, and how it changes through interaction with the environment. The following sections provide some readers a refresher and other readers a primer of information about the brain, which will facilitate the understanding of what is to follow in this book. We first review the basic organization of the nervous system and the brain structures that are relevant for language, learning, and cognition. Then we cover neurologic development through the gestational period. This material provides the background for Chapter 2. In Chapter 2 we discuss brain development during the postnatal, childhood, adolescence, and early adulthood periods, neural systems or cortical networks, and how the brain is organized for learning and processing information.

### CORTEX

The *central nervous system* is composed of the *brain* and *spinal cord*. Although these are two parts of an integral system, this book's focus is on the brain because it is the portion of the central nervous system that is primarily involved in language and learning. The brain is composed of *cortical* (cortex) and *subcortical* structures. The cortex is divided into two *cerebral hemispheres*, each having separate and *homologous* (corresponding or similar) functions.

The surface of the cortex is characterized by an interfolding of *gray matter*. Gray matter is composed of *neurons* or nerve cell bodies. The interfolding of the gray matter results in *gyri* and *sulci* (Figure 1–1). Gyri are the "hills" or elevations and sulci are the "valleys" or depressions of the cortical surface. The gyri and sulci increase the available surface area of the cortex while not increasing the overall size of the brain. Therefore, more computational power is available without having to have a bigger brain.

In addition to the neurons, the cortex is composed of *glial* cells. These are cells that provide support and nutrition to the neurons and insulation between neurons. Without the glial cells, the neurons cannot survive and perform their functions.

ration of the frontal lobe in autism (Luna et al., 2006). Consistent with an abnormal trajectory of development, all autism age groups had difficulty with response inhibition and spatial working memory; however, speed of sensorimotor processing and voluntary response inhibition were less affected in the older age groups.

## FUNCTIONAL IMAGING OF LANGUAGE IN AUTISM

A central implication of the complex information processing model of autism is that the cognitive deficits are dynamically realized as an individual with autism processes information. Therefore, to capture the nature of the neurobiological basis of autism, measures that allow examination of neurofunctioning during the performance of cognitive tasks are needed. Functional magnetic resonance imaging (fMRI), a noninvasive neuroimaging method that allows examination of neurofunctioning during the performance of cognitive tasks, has provided a unique opportunity to investigate the cognitive processing of individuals with autism. Functional imaging studies have covered an array of areas such as auditory processing (Gervais et al., 2004), social cognition (Kana et al., 2008), executive function (Just et al., 2007), face processing (Schultz, 2005), and visuospatial processing (Hubl et al., 2003). Functional MRI studies have revealed both areas of intact processing and, more interestingly for the design of intervention, areas in which individuals with autism have differed in the use of processing resources even when they did not differ in behavioral performance. Because our primary interest is in language and learning in autism, we focus our discussion on the functional imaging studies of language and auditory processing.

The first reported fMRI study of language processing in autism investigated brain function as adults with autism read sentences (Just et al., 2004). The results indicated that the adults with autism processed language using language areas of the brain. However, the autism group had relatively greater activation in Wernicke's area (posterior left superior and middle temporal gyri) than in Broca's area (left inferior frontal gyrus) as compared to age and IQ-matched controls (Just et al., 2004). The functional connectivity measure, or the degree of synchronization or correlation of the time series of the activation, indicated that the language network of the autism group was not as well synchronized as the controls. The difference in functional connectivity was particularly apparent in the frontal and posterior connections.

A similar pattern of reduced Broca's activation and increased Wernicke's activation was reported in another fMRI study of adult males with autism that used a single-word semantic judgment task (Harris et al., 2006). The implication of these two studies is that in language tasks in which the individuals with autism did not differ from the age and ability matched controls, there were underlying neurofunctional differences. These neurofunctional differences suggest differences in language processing in individuals with autism. The nature of these language processing differences is only speculative at this point. Just et al. (2004) suggested the relatively increased Wernicke's/reduced Broca's activation was consistent with a word-by-word processing approach rather than an integration of meaning. Furthermore, the Harris et al. (2006) task was a semantic decision task rather than a sentence processing task and a similar pattern was observed. Harris et al. interpreted their findings as consistent with behavioral studies that indicate difficulty with encoding of semantic aspects of verbal material in autism. The results from these two studies suggest the possibility that semantic processing (as well as syntactic processing) may be qualitatively different in autism.

How individuals with autism process language with social cognition demands has also been investigated. Wang, Lee, Sigman, and Dapretto (2006) used fMRI to examine the processing of irony in male children 7 to 16 years of age with high functioning autism or Asperger syndrome. Irony is a form of language that is of interest in autism because it requires the sharing of beliefs and knowledge between the speaker and listener for accurate interpretation. The participants listened to short scenarios and had to decide whether the speaker was being ironic or sincere. Three conditions were used—event knowledge only (contextual cues delivered in a neutral tone), prosodic cues only (no contextual cues but different intonational patterns), and event knowledge + prosodic cues (contextual cues with congruent intonational patterns). The children with autism had greater activation than the typical children in right inferior frontal gyrus and the bilateral temporal regions. This activation pattern was within the network recruited by the typical children and was thought to represent an increase in effort. However, despite the neural indication of increased processing effort, the children with ASD had more difficulty than the typical children with interpreting the ironic remarks, especially when they had to integrate contextual and prosodic information.

Another fMRI study was designed to investigate working memory in autism but also provided information on how individuals with autism process visual language symbols. Koshino et al. (2005) used a visually presented *n*-back letter task to examine the verbal working memory processes of individuals with autism. This is a classic working memory task. Three conditions were used: 0-back in which the respondent pressed a button every time a target letter appeared on a computer screen; 1-back in which the respondent pressed a button when two letters in a row were the same (H-G-G); and 2-back in which the respondent pressed a button when two letters separated by another letter were the same (H-G-A-G). As expected, the brain activation of the normal controls indicated a left hemispheric working memory network with left frontal and parietal regions. The brain activation of the autism group was also a working memory network, but this network consisted of the *right* frontal and parietal regions. This is a network typically seen when individuals are performing a visual or spatial working memory task. The autism group appeared to be remembering the letters as visual-graphic codes rather than recoding the information linguistically (e.g., saying the names of the letters). It is not known if this failure to recode visual information linguistically is unique to this type of working memory task or if it is a common feature of the cognitive processing of individuals with autism. Failure to automatically associate visual objects with their names would interfere both with comprehension and production of language.

An fMRI investigation of visual imagery provided additional information about the relationship between visual and language processing in autism. Kana et al. (2006) investigated the processing of visual imagery in individuals with autism using two conditions: (1) sentences that invited visual imagery during comprehension or High Imagery sentences (e.g., *The number eight when rotated 90 degrees looks like a pair of spectacles)*; and (2) sentences that did not need visual imagery for comprehension or Low Imagery sentences (e.g., *Addition, subtraction, and multiplication are all math skills*). The autism group activated parietal and occipital brain regions associated with imagery processing during comprehension of both the high and low imagery sentences. In contrast, the controls primarily activated these regions when comprehending sentences with high imagery. The autism group used brain regions that typically are used for imagery processing even when the language did not require it, drawing more heavily on visual areas than language areas when completing this language task. The functional connectivity measure of coordination between the language and spatial centers was also relatively lower during visual imagery for the autism group in comparison to the normal controls.

The role of perceptual components, thought to be visual imagery, during semantic decision making was demonstrated in another fMRI study with older adolescents and adults with autism (Gaffrey et al., 2007). This study used a semantic decision task (a yes/no button response as to whether or not a word belonged to a target category). Whereas the significant area of activation for the control group during the task was in the left inferior frontal gyrus (Broca's area), the significant area of activation for the autism group was in extrastriate visual cortex bilaterally. The authors suggested that these findings were consistent with atypical organization of the lexical-semantic system in autism with a greater reliance on perceptual aspects when learning about objects and their associated word labels.

Discourse processing is of interest in autism because it requires the integration of the language and theory of mind networks. It is generally accepted that individuals with autism have difficulty making inferences during discourse processing (Dennis, Lazenby, & Lockyer, 2001; Jolliffe & Baron-Cohen, 1999a; 1999b). However, it is not clear if they only have difficulty when the inferences are about human intentionality (theory of mind) or if they have difficulty with other types of inferences. Behavioral research suggested that individuals with high functioning autism could make inferences about physical states but had more difficulty with inferences about mental states (Happé, 1994; Jolliffe & Baron-Cohen, 1999a). In an fMRI study of reading discourse, three different types of passages were used: (1) one that required inferring the physical causation; (2) one that required inferring the internal motivation of a protagonist; and (3) one that required inferring the emotional reaction of a protagonist (Mason, Williams, Kana, Minshew, & Just, 2008). As expected, the control participants recruited the right temporoparietal region only when theory of mind processing was invited by the content. However, the autism group activated this theory of mind region during all three conditions. The brains of the autism group used a similar processing pattern even as the demands of the task changed. In addition, the autism group had lower functional connectivity than the controls both within the theory of mind network and between the theory of mind and left hemisphere language networks. The brain activation and functional connectivity results suggested that the autism group had a theory of mind network; however, it did not function in the same way as that of the control participants.

These fMRI studies suggest that the language processing differences in autism reflect neuroanatomic and neurofunctional differences. Even though individuals with autism may perform language tasks similarly at a behavioral level, they may be using a cognitive processing pattern that is different from that used by typically developing individuals. Even when individuals with autism successfully process language, they may be using the upper limits of their linguistic processing resources. When processing some forms of language, individuals with autism may rely on visual processing areas to a greater degree than typically developing individuals. When the processing demands of the task increase, individuals with autism may not have additional processing resources to draw upon, resulting in a breakdown in task performance.

These underlying processing differences have been interpreted as indicators of the way the brain in autism has accommodated itself so that language can be learned and used. However, these processing differences also offer hints as to why individuals with autism have persistent differences in language function. The neurofunctional differences suggest that, as suggested by some behavioral studies, the language processing system is qualitatively different in autism.

## AUDITORY PROCESSING IN AUTISM

Individuals with autism demonstrate difficulty with the processing of spoken language (Minshew et al., 1997; Williams et al., 2006a). Difficulty with auditory processing appears to be an early occurring feature of autism. Children with autism have been reported to have a lack of preference for their mother's voice (Klin, 1991). An fMRI study of adults with autism indicated that they had significantly less brain activation in bilateral superior temporal sulcus regions when listening to vocal sounds than age-matched controls

(Gervais et al., 2004). These brain regions are considered to be voice-selective regions. In contrast, the autism group did activate this area in response to nonvocal sounds. The level of activation for the autism group was similar for both vocal and nonvocal sounds, failing to show a differential response to vocal stimuli.

Event-related potentials (ERP) have been used to demonstrate that children with autism have normal processing of simple and complex sounds and normal orienting to changes in these sounds; however, involuntary orienting to vowel changes was absent in these children (Ceponiene et al., 2003). This was interpreted as indicating that the failure of children with autism to orient to speech is not due to sensory deficits but may be speech-sound specific.

PET studies with children and adults with autism suggest that the left temporal regions, which should be specialized for the perception and integration of complex sounds, do not function normally in children and adults with autism (Boddaert et al., 2003; Boddaert et al., 2004). The children and adults with autism did not demonstrate the expected left hemisphere asymmetry in the superior temporal cortex. They also demonstrated significantly less activation than the control groups in the left middle temporal gyrus (BA 21, 39) and the left precentral gyrus (BA 6, 43). Children and adults with autism appear to have dysfunction in the temporal regions which typically are used for the differential processing of human speech and the integration of complex auditory information.

## IMPLICATIONS FOR LEARNING IN AUTISM

Based on the results of the neuropsychological and neuroimaging studies reviewed above, it is clear that individuals with autism do not learn in the same way as typically developing children even when they demonstrate similar behavioral performance. However, it is generally accepted that associative learning is intact in autism (Boucher & Warrington, 1976; Williams, Goldstein, & Minshew, 2006b). In fact, it is this strength in associative learning that has been capitalized on for intervention approaches such as discrete trial learning that has been used successfully to expand the communication skills of children with autism (Goldstein, 2002). Related to this strength in associative learning, we know that children with autism can learn when information is simpler and when what is to

SLI/LLI, will interfere with the development of language because the disorder interferes with brain development and alters the way the brain responds to environmental input. This differential response may affect the process of brain development. Therefore, the brain of a child with a developmental language disorder will have a different developmental trajectory both because the underlying genetic code is altered, and because of a differential response to environmental input. An interventionist cannot control the underlying genetic code and cannot control the way the brain processes input. However, an interventionist can alter environmental input to help optimize learning for a child with a developmental language disorder.

It is important to remember that, although language comprehension and production involve language-specific brain mechanisms, more general cognitive resources in the brain are also incorporated into various types of language processes. These may be more or less affected in different developmental language disorders. These more general cognitive mechanisms were discussed in Chapter 7 and need to be considered when assessing and planning intervention for children with developmental language disorders.

Research about the differences in neurobiological development for children with disorders is ongoing and, therefore, the nature of these differences is not yet well-characterized. However, behavioral differences for these children are evident and are well-documented, and these behaviors are assumed to reflect differences in brain development. Brain-based assessment and intervention for children with developmental language disorders will reflect an integration of neurobiological research and behavioral research related to brain function.

## CONSIDERATIONS FOR OLDER CHILDREN AND ADOLESCENTS

When designing interventions for older children and adolescents with neurodevelopmental disorders, you must consider two primary factors. The first factor is the limits imposed by the age or the stage of neurologic development of the individual. As described above, brain development continues through early adulthood. However, the brain is capable of different types of changes at different times during that period. For example, the sensitive periods for language development are during the preschool years, whereas major changes in frontal lobe development occur throughout adolescence and young adulthood. The second primary factor that has an impact on intervention with individuals with neurodevelopmental disorders is the limits imposed by the particular type of disorder that the older child and adolescent has. For example, children with SLI/LLI may be able to develop alternate strategies using other cognitive processes that are not significantly affected by their disorder. Children with autism may be more challenged because their disorder affects all of the cognitive domains, making the development of alternate strategies difficult.

Neurodevelopmental disorders place biological constraints on development and learning. However, evidence from research studies and clinical reports indicate that children and older adolescents with neurodevelopmental disorders do learn and change. The hope is that greater understanding of the biological basis of how this learning occurs will guide us in the design of even more effective interventions. The job of the interventionist is, first, to learn as much as possible about the way the brain of the child handles input from the environment and, second, to work within that biological constraint to promote as much learning as possible. When a child has a developmental language disorder, environmental input will need to be changed in order for learning to occur. What types of changes are needed will vary from disorder to disorder and child to child. If the interventionist makes facilitative adaptations, progress and learning will be enhanced and the child will demonstrate growth in language skills.

## BRAIN-BASED ASSESSMENT WITH OLDER CHILDREN AND ADOLESCENTS

As discussed in Chapter 8, at the present time, there are no clinical neurofunctional measures that will yield information about how a child's brain functions when learning or using language. Therefore, assessment of brain function in regard to learning and development is based on behavioral measures. There are different models for the behavioral assessment of brain function.

Psychologists may use *neuropsychological* instruments and procedures for assessment (Lezak, Howieson, & Loring, 2004). As the name implies, this type of assessment was designed to measure behaviors thought to be associated with brain functions. The assessments are commonly divided into different cognitive domains, representing the sensory/perceptual and associative functions of the major divisions of the brain. Cognitive skills typically assessed are attention, perception, memory, visuospatial, language, executive function, and concept formation and reasoning. Within the language domain, typical skills that are assessed with neuropsychological measures are naming, vocabulary, discourse, and verbal fluency. Written language skills including reading, writing, and spelling also are commonly assessed. These measures do not differ significantly from those obtained by the standardized test instruments speech-language pathologists usually use with older children and adolescents. Therefore, a speech-language pathologist could administer a standardized test of language function and interpret the results related to brain function.

Assessment of older children and adolescents with developmental language disorders also may be made using an information processing model (Gillam, Hoffman, Marler, & Wynn-Dancy, 2002). This type of assessment would include measures of bottom-up or perceptual processing of auditory and visual input and top-down processing or the way higher-order thinking affects behavioral performance. Considerations of the various mechanisms of attention and the various components of working memory would be part of the assessment process. Some behaviors that can be observed to assess the capabilities of an older child or adolescent for language processing and production are listed in Table 9–1. These behaviors include processing-related correlates for the major aspects of language—syntax/morphology, phonology, semantics, and pragmatics.

An information processing assessment should go beyond documenting whether or not a child has a particular skill. Consideration should be given to the level and amount of language information that the child can handle. The contexts in which language processing appears to be adequate and when it falters should be determined. Many of the skills listed in Table 9–1 should be exhibited at younger ages. Older children and adolescents may demonstrate difficulties in these areas as the demands for language processing and production increase. For example, older children and adolescents are expected to integrate larger units of discourse and to handle different types of discourse. A child may have had adequate conversational skills at a younger age but fail to meet the high social demands of

**Table 9–1.** Behaviors to Assess Capabilities for Language Processing and Production

- Language-related executive functions
  - verbal working memory
  - language organization
  - verbal reasoning
- Phonological processing/awareness
- Semantic system
  - word retrieval
  - rapid automatic naming
  - semantic organization
  - multiple meanings
- Syntax
  - grammatical structure in the sense of error detection
  - using grammar
- Pragmatics
  - flexible language use
  - theory of mind
- Integration (for both comprehension and production)
  - inferencing (physical, emotional, mental)
  - discourse processing (conversational, narrative, expository)

adolescent conversation. Older children and adolescents must be able to both comprehend and produce narratives to share personal stories with others to establish social closeness. Adolescents spend increasing amounts of time processing expository discourse, a challenge that was less frequent at a younger age.

The assessment process should determine *what* about the task is difficult for the child. Difficulties with discourse may arise because the child does not have the underlying cognitive structure and/or because the child has difficulty with comprehending or producing the language that expresses that structure. Determining where the breakdown occurs will be important for determining what type of intervention to implement.