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# How the Brain Thinks in Autism: Implications for Language Intervention

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Autism or autism spectrum disorder (ASD) is usually thought of as a behavioral and social communication impairment. However, it is a broad-based neurodevelopmental or brain-based disorder that is the result of genetic events that occur prior to birth with widespread effects on cognitive and socio-emotional development (Geschwind, 2009). Autism clearly affects social functioning, but it has an impact on the development and use of language that extends beyond pragmatics.

Autism is a spectrum disorder that can range from mild to severe with varying levels of effect on language. Approximately 30% to 40% of individuals with ASD are considered high-functioning (Fombonne, 2005). Most individuals with autism are capable of communicating verbally, although the amount of verbal communication may be significantly limited for some.

Because ASD is a neurodevelopmental disorder, clinicians will benefit from understanding what is different about the brains of affected individuals. Neuropsychological studies completed with high-functioning adults and children with autism have yielded a profile of intact and impaired abilities (Minshew, Goldstein, & Siegel, 1997; Williams, Goldstein, & Minshew, 2006a). Simpler abilities or skills that can be completed with lower-order brain circuitry are intact or enhanced in ASD. These simpler abilities include basic attention, elementary motor, sensory perception, simple memory, formal language (including phonological and grammatical elements), rule-learning, and visuospatial processing.

Higher-order cognitive abilities or those that require integrative processing are disproportionately impaired in ASD. Affected abilities occur across the cognitive domains and include complex sensory, motor, memory, and language skills as well as concept formation (Minshew et al., 1997; Williams et al., 2006a). Even in the visuospatial domain, integrative skills such as face recognition may be affected (Behrmann, Thomas, & Humphreys, 2006).

The neuropsychologic profile defines deficits considerably beyond the three major impairments—social reciprocity, communication, and repetitive and stereotyped behavior—that have been used to define ASD. These findings suggest a more brain-wide disturbance in information processing and its neuronal architecture consistent with a disorder of neuronal organization. Neuronal organization refers to the composition of the neuronal layers of the brain and the billions of interconnections among neurons. In utero and during development, neuronal organization emerges through many processes, including synaptogenesis (the formation of new synapses or junctions by which one neuron communicates chemically with another neuron) and dendritic arborization (the formation of the branched projections of the neuron cell body that pass on the neural signal received from other neurons through the synaptic junction). The communication between neurons is thought to be affected in ASD (Geschwind & Levitt, 2007).

## **A Disconnection Syndrome**

The inference from the profile of strengths and weaknesses in ASD is that higher-order brain circuitry is underdeveloped. Individuals with ASD, therefore, appear to rely on lower-order circuitry to function (Williams et al., 2006a). Current models suggest that ASD is a disconnection syndrome (Minshew & Williams, 2007) in which regions of the brain that should function together smoothly and efficiently to perform an information-processing task are affected. Initial evidence of this disconnection came from an fMRI study of sentence-reading comprehension in adults with ASD (Just et al., 2004). These individuals processed language in the left-hemisphere language areas similar to typical age- and IQ-matched peers, although they had relatively more activation in Wernicke's area (semantic processing) than in Broca's area (sentence integration) of the brain. Most importantly, the coordination of the processing in these two areas was significantly reduced in the adults with ASD as compared to their typical peers. Further evidence of this functional underconnectivity, particularly between frontal and posterior brain regions, comes from several fMRI studies (e.g., Just, Cherkassky, Keller, Kana, & Minshew, 2007; Mason, Williams, Kana, Minshew, & Just, 2008). Structural MRI studies also have documented differences in white-matter volume and white-matter tracts in individuals with ASD (e.g., Alexander et al., 2007; Conturo et al., 2008).

## **Difficulty With Prototype Formation**

Because of their brain function differences, individuals with ASD learn differently about the world and people. For example, they learn categorical information without the help of the automatic mechanisms that allow typically developing infants to form prototypical representations of information spontaneously (Gastgeb, Strauss, & Minshew, 2006). Therefore, abilities that rely on the formation of prototypes—such as facial recognition, emotional expression, and the organization of information into different categories—are affected in ASD. Individuals with ASD must develop their own idiosyncratic strategies for performing categorical organization and discrimination tasks.

The recall of myriad detailed information by individuals with ASD is frequently cited as one of their extraordinary abilities. However, this behavior is actually an indication of their failure to form schemata or paradigms spontaneously to organize information (Minshew & Goldstein, 2001;

Williams, Goldstein, & Minschew, 2006b). Categorization occurs automatically in most learners, reducing the information-processing load and allowing the individual to use experiential knowledge flexibly and to store it in a form that is easier to convey to others.

Difficulty in determining the salient or most important information in a given situation is related to the difficulty with prototype or concept formation in ASD. The brain of a typical learner quickly allocates information-processing resources to the most salient information with minimal awareness on the part of the learner.

The difficulty with saliency in ASD has been examined primarily in the area of visual processing. For example, research on face-processing indicates that when individuals with autism look at faces, they focus more on the mouth than on the eyes, although the eyes carry more information about the emotional state and thoughts of the person (Klin et al., 2002; Pelphrey et al., 2002). This behavior is thought to be driven by difficulty with the top-down processes that are typically involved in the allocation of visual attention (Neumann, Spezio, Piven, & Adolphs, 2006). Research also suggests, however, that perceptual alterations may be present in ASD (Behrmann et al., 2006). Because they have difficulty automatically determining saliency, children with ASD have a more idiosyncratic focus. One child may focus on color and be drawn to brightly colored objects; another may focus on the texture of objects; a third may be drawn to auditory input and be distracted, for example, by the high-pitched hum of fluorescent lights.

## **Development of Language in Autism**

A neurodevelopmental condition like ASD interferes with language development because it interferes with brain development and alters the way the brain responds to environmental input. In the typical developmental process, the brain has certain capabilities—such as detecting similarities or patterns in input—that make it ready to learn language (Kuhl, 2000). Environmental input interacts with these genetically controlled abilities to shape the developing brain (Knudsen, 2004). When a child has a developmental language disorder such as ASD, the effects of the disorder begin to occur even before the recognition that the child is developing differently (Geschwind & Levitt, 2007). Like all developmental disorders, ASD continues to influence the child's brain function and development across the lifespan (Karmiloff-Smith, 2009).

In addition, the child's brain may develop alternative information-processing strategies that may either facilitate or interfere with optimal brain function. Therefore, in ASD two major factors influence a child's ability to learn and use language: 1) the inherent early-occurring brain differences and 2) the response of a brain with these biological constraints to environmental input.

Early in the developmental process, a child with a typically developing brain can differentiate speech from nonspeech, discriminate words within a stream of connected speech, relate the words to objects and actions in the environment, discriminate sentences within continuous discourse, relate the meaning of one word to another word, and interpret language based on contextual knowledge (Bates, 1993; Friederici, 2005; Smith & Yu, 2008). These tasks are difficult for children with ASD; they often fail to respond to their own names and lack a preference for their mother's

voice (Klin, 1991; Nadig et al., 2007). Verbal children and adults with ASD may repeat "chunks" of language such as television commercials—a sign of holistic storage of information with a failure of analysis and integration (Wetherby & Prizant, 2005). They may repeat a question instead of answering, use complex sentences before naming objects, speak with an unusual intonation pattern, and have difficulty attending to and comprehending spoken language.

Neuroimaging studies have provided some clues to the underlying neurofunction related to these behaviors. For example, PET studies with children and adults suggest that the temporal lobes, typically used for the differential processing of human speech and the integration of complex auditory information, demonstrate unexpected patterns of function in individuals with ASD (Boddaert et al., 2003; Boddaert et al., 2004). An fMRI study of adults with ASD failed to show a differential brain response to vocal stimuli as compared to nonvocal stimuli (Gervais et al., 2004). These studies suggest that language learning is a greater challenge for children with ASD because the ability of their brains to use the auditory input differs from that of other children.

## **Why Language Production Is Difficult**

The lack or reduced use of spoken language by children with ASD is thought to result from a range of underlying problems, including difficulties with the perception of human speech, parsing words from the speech stream, or mapping words to objects or other environmental information (Tager-Flusberg, Paul, & Lord, 2005; Wetherby & Prizant, 2005). Any of these problems could affect the stored representation of the word and potentially interfere with later retrieval of the word to speak.

Alternately, children with ASD may have dyspraxia-related difficulty creating the articulatory motor plan required for spoken word production (Mostofsky et al., 2006). It is difficult to study language production in ASD with current neuroimaging techniques because speech production creates extraneous head movements that interfere with the interpretability of the imaging data. However, results from at least two fMRI studies with written language have given some insight into the language processing difficulties associated with ASD.

A study of verbal working memory (Koshino et al., 2005) indicated that when typical peers viewed a letter, they automatically recoded it into the name of the letter, processing the information in the left-hemisphere language and frontal working memory brain regions. However, when adults with ASD viewed a letter, they processed the information in the right-hemisphere visuo-graphic brain regions, failing to recode the information linguistically. A reduced propensity to process linguistic information in the left-hemisphere language areas could interfere with spoken language development.

A second fMRI study (Kana et al., 2006) indicated that individuals with ASD used brain regions associated with visual processing or visual imagery even when the language task did not require it, suggesting that information that should be processed using language areas is initially processed visually. These studies provide a possible explanation for why use of visual aids has been successful in developing communication, spoken language, and social skills in children with ASD (Sulzer-Azaroff, Hoffman, Horton, Bondy, & Frost, 2009; Charlop-Christy & Daneshvar, 2003).

## Implications for Language Intervention

We are at the forefront of understanding the neurobiological basis of ASD and, in particular, the use of fMRI to study the learning process in ASD is in its infancy. Functional imaging has been used with individuals with dyslexia, another developmental language disorder, to show that intervention can result in changes in neurological function and structure (Shaywitz et al., 2004; Simos et al., 2007; Temple et al., 2003). There are no similar studies with individuals with ASD. However, just as speech-language pathologists have long applied knowledge from studies of normal language acquisition to the design of intervention for children with developmental disorders, the knowledge gained from neuroimaging and associated behavioral research can be applied to advance interventions for children with ASD.

An SLP cannot change the way the brain of a child with ASD processes language, and as a result cannot change the way the child learns or produces spoken language. However, a clinician can determine how to adapt the input and support the output to accommodate information-processing differences. The SLP and communication partners can do the work that the brain of the individual with ASD cannot do. They must determine the information-processing limits, interferences with learning, and most helpful input/output modalities for each individual with ASD.

In what ways can the environmental input be changed to help a child with ASD? Because of the difficulty most children with ASD have processing language and determining saliency, a starting point is to make the important information obvious or explicit. For example, use fewer words so that a child need not separate the relevant word from the spoken language stream—"car" versus "the car is going fast." For young children who are in the process of acquiring language, a word must be clearly paired with the environmental referent. Whenever possible, a child should handle the object as it is named, reducing the possibility of a focus shift to an unintended object in the environment.

Because children with ASD have difficulty developing prototypes, adults must provide large numbers of exemplars so that the brain has adequate input from which to learn and make associations. The first example of a concept should be, if possible, the most prototypical rather than an atypical member of the class, with additional examples introduced after the initial concept has been learned. Further, behavioral research suggests that children with ASD may need extreme examples when learning abstract concepts such as labels for emotions (e.g., happy, sad, mad) (Gastgeb et al., 2006).

Connections between visual information and auditory information need to be developed explicitly for children with ASD. Two long-used therapeutic techniques that may help to make these auditory–visual connections for children with autism are picture exchange systems in which a single spoken word is clearly connected to a photograph of the word (see Charlop-Christy & Jones, 2006) and aided language stimulation, which uses visual representations paired with spoken language during interactive play (Goossens, Crain, & Elder, 1992; Harris & Reichle, 2004).

## **Beyond Intervention for Social Communication**

A neurobiologic/neuropsychologic model of ASD indicates that affected individuals have difficulty with adaptive function for reasons that go beyond their difficulty in processing social information. Social information requires attending to and integrating large amounts of information. Therefore, intervention with older students with high-functioning ASD needs to focus on more than learning social rules and holding conversations. In this respect, students with ASD are very similar to students with language-learning disabilities, and many of the intervention techniques used with that population can be used with students with ASD. For example, the amount of information presented at one time may need to be reduced because students with ASD cannot process large amounts of information efficiently. Graphic organizers may help a student by reducing the amount of information that must be held in working memory as a written or verbal utterance is being formulated. Clinicians should be aware of the extent of the information-processing load entailed by a task and reduce the load or provide more processing time as appropriate.

Rather than asking students to learn large amounts of detailed or factual information (although this may not be difficult for them), the focus should be on helping them to understand the main idea or how new information is associated with previously learned information. For example, a graphic organizer could be used as a visual depiction of the hierarchical arrangement of factual information (such as the various battles of the Civil War) to the more abstract ideas (why the Civil War was waged). A prodigious memory for interesting but disconnected facts should not be confused with an understanding of abstract relationships.

## **Supporting the Learning Process**

Arguably, clinicians can support the communication and social development of individuals with ASD more effectively if they understand more about their underlying neurophysiologic and cognitive differences. Even though the behavioral performance of individuals with ASD sometimes may appear similar to that of typically developing individuals, the underlying brain function likely is not similar. Environmental input can influence their learning but cannot change the basic underlying neurophysiologic differences characteristic of autism. Individuals with ASD cannot control the way they learn and think about the world. They depend on SLPs, teachers, families, and caregivers to help them navigate what must be a noisy, confusing environment.

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## Autism and fMRI

- **High-functioning autism (HFA)** describes individuals who meet the criteria for autism but who have IQ scores equal to or greater than 70. Low-functioning autism (LFA) describes individuals with autism who have moderate to severe intellectual impairments with IQ scores below 70.
- **Functional magnetic resonance imaging (fMRI)** is a research application of magnetic resonance imaging (MRI) technology in common clinical use. During an fMRI scan, the participant performs a cognitive task, typically responding to experimental items presented on a computer screen. After processing the data, the researcher can measure the hemodynamics (or changes in blood flow and blood oxygenation) in groups of neurons that are related to cognitive activity. Functional connectivity is a measure that compares the timing of the hemodynamic response in two different brain regions.

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