Speech in Autism Spectrum Disorder

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Autism spectrum disorder is a rich, understudied area for scientists interested in the development, production, and perception of speech.

Introduction

Autism, or autism spectrum disorder (ASD), begins in early childhood and is characterized by impairment in two main areas: (1) difficulty with social communication and (2) the presence of repetitive behaviors and/or restricted interests (American Psychiatric Association, 2013). ASD is diagnosed by careful clinical observation of a person's behavior or by interviewing a parent about a person's early development. ASD runs in families; ~90% of identical twins of people with ASD and 20% of fraternal twins or nontwin siblings of people with ASD also have diagnoses of ASD (Frietag, 2007), although the inheritance mechanisms are unknown. Many researchers are working to develop objective diagnostic markers such as biological tests or neuroimaging findings (Zwaigenbaum et al., 2013), and

Figure 1. *Language is made up of signed or vocally pronounced words, their meanings, and rules for combining words into sentences. Speech is one modality along with writing and sign language in which language can be expressed.*

a variety of differences in brain structure and function have been found. These range from differences in neural synapses (Zoghbi, 2003) to changes in the size of certain brain regions (Courchesne et al., 2007) to differences in how local and remote brain areas are connected (Mostofsky and Ewen, 2011). A full description of the neurological findings in ASD is beyond the scope of this article, but see Rapin (2011) for a compact and informative review.

People with ASD range from individuals of above-average intelligence to those who are minimally verbal (i.e., they know fewer than 20 words; Kasari et al., 2013). Current estimates are that approximately 1 in 68 children will be diagnosed with ASD (Centers for Disease Control and Prevention, 2010) and that about one-third of them will remain minimally verbal into adulthood (Rapin, 2011). Language, which has been described as "a system of symbolic representation that is used to communicate meanings, feelings, ideas, and intentions" (Levine et al., 1999), has been studied extensively in ASD. But speech, the ability to vocally articulate the sounds of language, has not. The relationship of language to speech is illustrated in **Figure 1**. This article is an introduction to why it is important to study speech in ASD, what is currently known about the topic, and what some particularly exciting avenues for further research are.

Speech Development in ASD

A small group of studies has examined speech development in ASD, with a few consistent results emerging. Before they are discussed, however, a point of clarification is in order. ASD cannot reliably be diagnosed in children until the age of approximately 3 years, and many children are not diagnosed until the age of 4 or 5 (Messinger et al., 2013). Thus, studies of development in ASD either include children who already have diagnoses or are prospective studies, performed before diagnostic status is known. One type of prospective study, the infant sibling study, has proved to be particularly revealing about the early development of children who develop ASD. In "infant sib" studies, two groups of children are recruited. Low-risk children have an older sibling without autism. The ASD diagnosis rate in low-risk children is the same as that in the population at large, about 1.5%. High-risk children have an older sibling with ASD, and up to one-fifth of high-risk sibs will themselves also receive a diagnosis of ASD. Another 50% develop typically (Ozonoff et al., 2014). The remaining 30% of high-risk siblings do not receive diagnoses of ASD but do show an increased prevalence of other difficulties, such as language disorder, attention deficit hyperactivity disorder, or mood disorder (Rutter, 2013). The current view is that a diagnosis of ASD results from a combination of traits, some of which are relative deficits and some of which are relative strengths. Part of the power of this view of ASD is that it seems to explain the variation in the syndrome. Another part of its power is that it puts a child's strengths more in the forefront, allowing us to understand better what abilities a particular child brings to the table and how we might capitalize on them in therapy. In fact, a recent change in the field is to view people with ASD as different, not deviant, and this has led to a change in nomenclature. Instead of referring to "autistic" and "normal" children, we use person-first language such as "children with ASD" and compare them with children who are "typically developing." This usage is intended to convey the idea that children whose development is not typical are not defective, and the "different, not deviant" view has also led to investigations of enhanced perceptions and skills in ASD (Mottron et al., 2006). Some researchers are attempting to understand the effect of deficits and strengths in different areas to understand how different combinations give rise to the variety of behaviors we see (Brunsdon and Happé, 2014).

Consistent findings in the development of speech in children with ASD are, first, that children who develop ASD babble significantly less often than typically developing children of the same age (Plumb and Wetherby, 2013; Patten et al., 2014). Children with ASD have also sometimes been found to produce a higher proportion of "atypical" vocalizations such as squeals, growls, and other non-speechlike vocalization types as opposed to vowel and consonant sounds like "bababa" (Paul et al., 2011; Schoen et al., 2011; Plumb and Wetherby, 2013). However, children with Down syndrome or cognitive delays also tend to babble less, so this finding may not be specific to ASD. Second, children with ASD show at least temporary delays in learning to pronounce the sounds of their native languages (Paul et al., 2011; Schoen et al., 2011). Some researchers have found delays in when children with ASD begin to say syllables with both consonants and vowels (Patten et al., 2014). Others have shown that children with ASD are slower to develop and use specific consonants or groups of consonants (Paul et al., 2011). Children who are delayed in developing consonants also often show slower progress in learning words, and some studies on toddlers with ASD have shown a relationship between speech delays and later vocabulary size or language ability (Paul et al., 2011; Plumb and Wetherby, 2013). However, we do not yet understand to what extent delays in consonant acquisition in children with ASD are due to autism itself rather than the result of a separate, accompanying disorder.

A final, striking aspect of the speech of some individuals with ASD is the presence of *echolalia*. Echolalia is an automatic repetition of spoken utterances a child has heard, either immediately after hearing the utterance or after a significant delay. Delayed echolalia is sometimes called "scripting"

or "movie talk" because children repeat lines from movies or televisions shows as if they were practicing a script. Some children use their echolalia to communicate with others, for example, reciting lines from a favorite book as a way of requesting that an adult to read to them or repeating instructions to themselves as a way of self-calming. Although echolalia sounds like it contains separate words and sentences (some children can repeat quite long quotes with uncanny accuracy), the general thinking is that children with echolalia use those utterances as if they were just one word, at least at first. Ron Suskind, a journalist whose autistic son spoke mainly in echolalia as a child, describes how he and his wife were able to use their son's movie talk to help him learn social and language skills (Suskind, 2014). Steigler (2015) contains a comprehensive review of the research literature concerning echolalia.

Speech Is a Spectrum in Autism, Too

Just as cognitive and language ability range from above average to significantly impaired in ASD, speech also forms a spectrum within the autism spectrum. It is no surprise that speech should be affected in ASD; impairments in communication, language, and motor ability are part of the definition of the syndrome. And to become a skilled user of speech, a person must have the desire and ability to communicate, must be capable of language, and must have the oral-motor ability to speak.

There are several areas in which the speech of people with ASD is unusual. One area is *prosody*, or stress and intonation, the "melody" of speech. Prosody includes variations in pitch, loudness, and length (the length of both words and pauses). Prosodic abnormalities in the speech of verbal individuals with ASD have been noted since the disorder was first described (Kanner, 1943). However, there is no consensus on how prosody differs between ASD and typical speech (see **Speech Findings in Verbal ASD**).

Another area in which the speech of many people with ASD differs is in *articulation*, the ability to correctly pronounce the sounds of one's native language. Speech errors are common in typical development: think of the way that some children say "w" for "r" as in "wabbit." But when errors such as these make a child unintelligible or when they persist past about the age of eight, a disorder is diagnosed. Articulation is impaired in almost half of the individuals with ASD (Rapin et al., 2009).

A final, almost unstudied area of speech production in ASD is that of *voice*, or how the larynx vibrates and how its sound is filtered by the upper vocal tract. As anyone who has ever had laryngitis knows, abnormal laryngeal vibration can make it very hard to be understood. Disorders such as hypotonia (low muscle tone) of the laryngeal muscles have also been associated with decreased intelligibility (Aronson and Bless, 2009), and because hypotonia affects approximately half of the children with ASD (Ming et al., 2007), it would be no surprise to find decreased intelligibility in hypotonic speakers with ASD.

Speech Findings in Verbal ASD

As mentioned in **Speech Is a Spectrum in Autism, Too**, the existence of differences in the speech of verbal individuals with ASD has been noted since the 1940s, and these differences have been described in a variety of terms (Shriberg et al., 2001). For example, the speech of verbal children with ASD has been described as "sing-song" as well as "wooden," "overprecise" as well as "mumbled" (Rapin, 1996). Amplitude and voice quality are often atypical, although again there is no consistent way in which these are different in ASD (Shriberg et al., 2001). Some people with ASD speak consistently too loudly, others too quietly, and still others breathily or roughly or with an odd timbre. Although abnormalities are not present in the speech of everyone with ASD, when they do occur they create an impression of oddness that is one of the greatest barriers to social acceptance and vocational success in otherwise capable individuals (Cleland et al., 2010). Parents of young adults with ASD know this all too well: one mother of a college-bound son with ASD wanted me to help him with his speech because she was afraid that when he went to apply for jobs, interviewers wouldn't think he was as smart as he was. But how common unusual prosody is in verbal individuals with ASD and how it compares to the prevalence in other populations are currently unknown.

Findings on articulation skills in verbal children with ASD vary. Some researchers have concluded that speech in ASD is delayed but not disordered (Bartolucci et al., 1976; Bartolucci and Pierce, 1977). Kjelgaard and Tager-Flusberg (2001) found that despite a large range of language ability in the group they looked at, speech articulation in the same group was within normal limits. But Cleland et al. (2010) found that over 40% of children with ASD produced at least some speech errors and that12% scored below the normal range on a standardized test of articulation. Similarly, Shriberg et al. (2001) found a 30-fold increase in the rate of speech errors persisting past the age of 8 years in ASD compared with about 1% in the general population. Of the participants in Rapin et al. (2009), 5% had below-normal scores on a standardized articulation test along with average language ability. Taken together, then, the literature suggests that speech production is relatively spared in verbal children with ASD, although these children do show a high rate of articulation errors. This is illustrated in **Figure 2**.

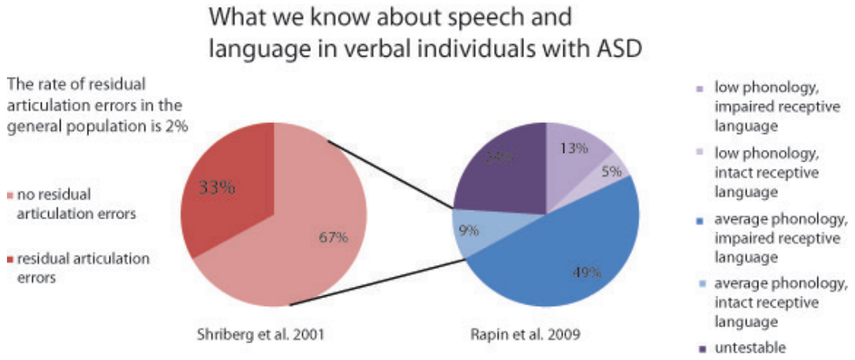

Figure 2. *These two interlocking pie charts show current estimates of the prevalence of phonological or articulation disorder in autism generally and in verbal autism specifically.*

Speech Findings in Minimally Verbal ASD

Few researchers have reported on speech ability in minimally verbal people with ASD. In part, this is because these individuals generally score so low on tests of language and cognitive ability that it is difficult to estimate their true abilities. When frustrated or frightened, some minimally verbal people also display aggressive behaviors toward property, other people, or themselves, so considerable experience and expertise is required to work with them. And, of course, testing the speech ability of a group of people who rarely vocalize (some of whom may not even be able to do so voluntarily) is inherently challenging. Speech ability is generally commensurate with language and cognitive ability in ASD (Tager-Flusberg, 1981); however, there have been reports of nonspeaking individuals with ASD who communicate by text and can read (Gernsbacher, 2004; Mottron et al., 2006). Clearly, this area requires more research.

Speech Perception in ASD

A small body of work describes speech perception in people with ASD. In typical toddlers, the brain develops in such a way that the left hemisphere gradually assumes more control over speech and language-related functions. This laterality can be demonstrated using EEG (electroencephalography); even just passively listening to varying speech sounds gives rise to a specific negative electrical brain wave in the left hemisphere, appearing approximately 150-250 ms after the stimulus (Kraus et al., 1993). Using passive-listening paradigms, some researchers have found that infants later diagnosed with ASD show a larger *right* hemisphere response to speech sounds (Seery et al., 2013) and that this difference relates to later language ability.

Interest in, or preference for, speech over nonspeech sounds and for child-directed versus adult-directed speech has been demonstrated in typical infants (Kuhl et al., 2005). Child-directed speech, or "motherese," is the high-pitched sing-songy way in which caregivers speak to babies. Kuhl et al. (2005) found that toddlers with ASD are less interested by motherese than toddlers without ASD, and Paul et al. (2007) found that toddlers with ASD who spent less time listening to motherese had lower language scores than control subjects. Social impairment thus affects speech and language acquisition, although how important and what its role is we do not know.

In older children with ASD, the ability to discriminate between small differences in the pitch, but not the duration, of sounds has been found to be equal to or better than in control subjects (Lepistö et al., 2006). The literature shows mixed results with respect to the ability of children with ASD to tell the difference between acoustically similar speech sounds. Some researchers have shown that people with ASD have an equal (Lepistö et al., 2005) or better (Lepistö et al., 2008) ability in the area of phonetic discrimination, but others have shown the reverse (Kasai et al., 2005).

Speech reception threshold, the lowest decibel level at which a person can identify two-syllable words like "hotdog" with 50% accuracy, has also been used to show differences between children with ASD and typically developing children. Children with ASD have higher (worse) speech reception thresholds in the presence of background noise (Alcantara et al., 2004). This has led to the conclusion that children with ASD experience difficulty understanding speech in noise, certainly a disadvantage when trying to understand directions from a teacher in a loud classroom, for example. The findings of both enhanced and deficient sound perception

may be explained by the fact that people with ASD show more right hemisphere activity than left hemisphere activity during speech or language processing (Haessen et al., 2011).

My Kingdom for a Theory

Three main frameworks exist for explaining the speech findings in ASD. One posits that *apraxia of speech* is responsible for the differences we see in the speech of verbal people with ASD and for the failure of some children with ASD to acquire spoken language at all (Shriberg et al., 2011). Apraxia of speech is "a speech sound disorder in which the precision and consistency of the movements underlying speech are impaired in the absence of neuromuscular deficits" (American Speech-Language-Hearing Association, 2007), and it means that while the muscles used for speech are fully functional, the ability to plan and sequence the movements required to fluently articulate speech is impaired. Apraxia affects all speech sounds to one degree or another, but a person can have apraxia of speech and no difficulty with other oral-motor actions like kissing or eating. Shriberg and Kwiatkowski (1994) estimate that about 1 in 1,000 children in the general population have apraxia of speech, but recent research by Tierney et al. (2015) found that approximately 64% of children with ASD also have symptoms of apraxia of speech.

A second framework comes from Warlaumont et al. (2014), who proposed that early social interactions with caregivers shape infants' speech production. In this view, when an infant attempts to produce speech sounds, but not squeals or moans, parents are more likely to respond with speech of their own. A speechlike response from an adult is more likely to then spur a child to produce more speechlike vocalizations and so on, in a virtuous cycle. ASD could diminish this feedback loop in three possible ways. First, less babbling means fewer opportunities for feedback for a child with ASD. Second, because of their social impairment, children with ASD might babble without looking at a caregiver. Lack of eye contact from the infant might result in the adult failing to realize that the infant was vocalizing to try to get his or her attention. The parent might then not respond, again decreasing the infant's opportunities for feedback. Finally, because children with ASD have difficulty interpreting other people's social reactions, they might not be as able to benefit from the feedback they do get from adults. Research from infant sibling studies has cast doubt on the idea that parents of children with ASD provide less or lower quality feedback (Talbott et al., 2013), but no research has been published bearing on the other two options.

A final framework, from Kwiatkowski and Shriberg (1993), views speech development as involving both cognitive/linguistic abilities and a certain level of focus on matching one's pronunciation to that of the other people in one's environment. In this view, verbal children with ASD possess the same underlying language and speech abilities as other children but do not focus on tuning their pronunciation up to the same degree (Shriberg et al., 2001; Paul et al., 2011). The social feedback loop framework may come into play here. If children with ASD are less able to monitor and adjust their own speech as they talk, they might appear unable to make use of adult feedback as well as other children.

More Work Needs to be Done

Clearly, much more work is needed to understand how speech is affected in ASD. First and foremost, a clear and detailed characterization of the range of speech ability across the autism spectrum is needed. We also need to investigate the mechanisms by which speech is affected. How many children with ASD show signs of apraxia? How many have articulation disorders or voice abnormalities? Is speech production ability in ASD related to language ability in the same way that it is in typical development? What is the relationship of speech production ability to cognitive level or severity of ASD symptoms? Perhaps spoken language impairment is one distinct condition that, combined with others, contributes to the variation we see in ASD.

In terms of speech perception and its relationship to speech production in ASD, one of the most basic questions to be answered is whether minimally verbal individuals with ASD perceive speech in the same way as do verbal individuals. For verbal people with ASD, how does their perception of speech sounds relate to their ability to produce them? Research on phonetic accommodation, mentioned in Robert Port's recent *Technical Committee Report* from the Speech Communication Committee (Port, 2015), raises an intriguing question. Are speakers with ASD as likely as speakers without ASD to spontaneously and unconsciously imitate intonation, timing, and other aspects of the speech of their conversational partners?

Speech production in ASD could also be compared with sign production in Deaf individuals with ASD. Recent research with Deaf children with ASD suggests that the proportion who fail to acquire sign is similar to the proportion of hearing children with ASD who fail to acquire spoken language (Shield and Meier, 2013). This suggests that it is a lack of capacity for language, not apraxia, that is responsible for these children being minimally verbal. However, apraxia may still be present in addition to a language disorder.

Much more research needs to be done to understand what treatment methods work for which children with ASD. Although special educators and speech pathologists have worked with the minimally verbal for decades (for example, Koegel, 1995; Wolf-Schein, 1985), no one form of therapy works for all children with ASD (but see Wong et al. [2015] for a comprehensive review of evidence-based therapies). The view of ASD as an accumulation of traits is important here. Understanding what methods work for whom promises better efficacy and efficiency than using a one-size-fits-all approach in the clinic.

Finally, research must also aim to understand the strengths of children with ASD. Characterizing ASD solely as a disorder blinds us to the possibility that these children have strengths that we could nurture (for example, enhanced pitch perception or less susceptibility to distraction by other people speaking). At the very least, understanding the strengths and interests of a child with ASD and incorporating those into therapy or a vocation can make the difference between a child who is dependent on his or her parents for life and one who can support him- or herself independently with a satisfying and rewarding job.

Considerations for Doing Research in ASD

I conclude with a short list of recommendations for doing research in ASD. First, given the range of performance of individuals with ASD on just about any test of speech, language, or cognition, it is important to include large numbers of participants. Ten to thirty per group is a bare minimum of participants for finding between-group differences.

Second, careful characterization not only of diagnosis but also of other abilities related to speech is important. Selecting participants with ASD who are as similar to each other as possible in terms of language and cognitive ability may make between-group differences harder to find but reduces confounds. Carefully consider the choice of a comparison group: simply comparing children with ASD with children without ASD may not be fine grained enough because the differences may be so pronounced as to be uninformative. Researchers have compared children with ASD with controls matched on language or cognitive ability or with children with non-ASD developmental delays. Other appropriate comparison groups, depending on the research question, might be nonautistic children with a speech delay of unknown origin, with a specific language disorder, or with attention deficit hyperactivity disorder.

Third, think through the experimental methods. Even highly verbal people with ASD may be bothered by sensory factors more than typical laboratory participants, meaning anything from needing more breaks during standardized testing to needing to discontinue testing because of an inability to tolerate wearing (say) the respiratory-inductive plethysmography sensors you are using. Longer opportunities to process information or to produce speech are especially important for cognitively impaired or minimally verbal individuals. Computerized, phonetically informed methods of speech analysis would be a tremendous asset here because this would enable scientists to analyze long speech samples more efficiently than by-hand analyses. For minimally verbal participants, of course, the choice of methods will be more limited than with highly verbal participants. Even tasks as seemingly simple as pressing one button in response to one sound and a different button in response to a second sound are quite complex for someone with low cognitive ability and may require a significant period of training before the task is learned well enough to consider the person's responses a reliable indicator of their perceptual ability.

Finally, hire the most experienced and dedicated staff you can to help you with this sometimes challenging population of individuals and pay them well. This is especially important if you choose to work with minimally verbal participants. People who work for group homes or residential schools for people with developmental disabilities, who have a high degree of respect for their clients, and who genuinely enjoy working with them are your allies in research. They will help you acquire the highest quality data and provide a positive experience for the participants with ASD and their families. These experienced and caring professionals can help you modify the aspects of experimental design and methods to work with the ASD population. And they are in the best position to help you understand the strengths as well as the challenges of each participant who visits your laboratory.

Conclusions

ASD is a rich, understudied area for scientists interested in the development, production, and perception of speech. People with ASD are a delightful, interesting, sometimes challenging group. Progress toward understanding the disorder and its effects on speech has deeply meaningful clinical applications in addition to advancing our understanding

of basic speech science. Finally, remember that because autism is a spectrum, we all possess some traits of the condition. Thus, people with ASD teach us about ourselves at the same time that we learn about them.

Biosketch

Karen V. Chenausky earned her SB in Linguistics and Philosophy from the Massachusetts Institute of Technology and her MS in Speech Pathology and PhD in Speech, Language, and Hearing Sciences from Boston University. She is a certified speech-language pathologist specializing in autism spectrum disorders. For 15 years, she also worked as a speech scientist for the Speech Technology and Applied Research Corporation, developing a particular expertise in the acoustic analysis of baby babbles. Currently, she is a postdoctoral researcher at Beth Israel-Deaconess Medical Center, working on a randomized clinical trial comparing two therapies to teach minimally verbal children with autism some words.

References

Alcantara, J., Weisblatt, E., Moore, B., and Bolton, P. (2004). Speech-in-noise perception in high-functioning individuals with autism or Asperger's syndrome. *Journal of Child Psychology and Psychiatry* 45, 1107-1114.

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual of Mental Disorders, 5th Edition*. American Psychiatric Association, Arlington, VA.

American Speech-Language-Hearing Association. (2007). *Childhood Apraxia of Speech* (Technical Report). American Speech-Language-Hearing Association, Rockville, MD.

Aronson, A., and Bless, D. (2009). *Clinical Voice Disorders*. Thieme, New York.

Bartolucci, G., and Pierce, S. (1977). A preliminary comparison of phonological development in autistic, normal, and mentally retarded subjects. *British Journal of Communication* 12, 137-147.

Bartolucci, G., Pierce, S., Streiner, D., and Eppel, P. (1976). Phonological investigation of verbal autistic and mentally retarded subjects. *Journal of Autism and Childhood Schizophrenia* 6, 303-316.

Brunsdon, V., and Happé, F. (2014). Exploring the 'fractionation' of autism at the cognitive level. *Autism* 18, 17-30.

Centers for Disease Control and Prevention. (2010). *Prevalence of Autism Spectrum Disorders Among Children Aged 8 Years: Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2010*. Morbidity and Mortality Weekly Report (MMWR) March 28, 2014/63(SS02), pp. 1-21.

Cleland, J., Gibbon, F., Peppé, S., O'Hare, A., and Rutherford, M. (2010). Phonetic and phonological errors in children with high functioning autism and Asperger syndrome. *International Journal of Speech-Language Pathology* 12, 69-76.

Courchesne, E., Pierce, K., Schumann, C., Redcay, E., Buckwalter, J. A., Kennedy, D. P., and Morgan, J. (2007). Mapping early brain development in autism *Neuron* 56, 399-413.

Frietag, C. (2007). The genetics of autistic disorders and its clinical relevance: A review of the literature. *Molecular Psychiatry* 12, 2-22.

Gernsbacher, M. A. (2004). Language is more than speech: A case study. *Journal of Developmental and Learning Disorders* 8, 81-98.

Haessen, B., Boets, B., and Wagemans, J. (2011). A review of behavioural and electrophysiological studies on auditory processing and speech perception in autism spectrum disorders. *Research in Autism Spectrum Disorders* 5, 701-714.

Kanner, L. (1943) Autistic disturbances of affective contact. *Nervous Child* 2, 217–250.

Kasai, K., Hashimoto, O., Kawakubo, Y., Yumoto, M., Kamio, S., Itoh, K., Koshida, I., Iwanami, A., Nakagome, K., Fukuda, M., Yamasue, H., Yamada, H., Abe, O., Aoki, S., and Kato, N. (2005). Delayed automatic detection of change in speech sounds in adults with autism: A magnetoencephalographic study. *Clinical Neurophysiology* 116, 1655–1664.

Kasari, C., Brady, N., Lord, C., and Tager-Flusberg, H. (2013). Assessing the minimally verbal school-aged child with autism spectrum disorder. *Autism Research* 6, 479-493. doi:10.1002/aur.1334.

Kjelgaard, M., and Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes* 16, 287-308.

Koegel, L. (1995). Communication and language intervention. In Koegel, R., and Koegel, L. (eds), *Teaching Children with Autism*. Paul H. Brookes Publishing, Baltimore, MD, pp. 17-32.

Kraus, N., McGee, T., Micco, A., Sharma, A., Carrell, T., and Nicol, T. (1993). Mismatch negativity in school age children to speech stimuli that are just perceptibly different. *Electroencephalography and Clinical Neurophysiology* 88, 123-130.

Kuhl, P. K., Coffey-Corina, S., Padden, D., and Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: Behavioral and electrophysiological measures. *Developmental Science* 8, F9–F20.

Kwiatkowski, J., and Shriberg, L. (1993). Speech normalization in developmental phonological disorders: A retrospective study of capability-focus theory. *Language, Speech, and Hearing Services in Schools* 24, 10-18.

Lepistö , T., Kajander, M., Vanhala, R., Alku, P., Huotilainen, M., Näätänen, R., and Kujala, T. (2008). The perception of invariant speech features in children with autism. *Biological Psychology* 77, 25–31.

Lepistö , T., Kujala, T., Vanhala, R., Alku, P., Huotilainen, M., and Näätänen, R. (2005). The discrimination of and orienting to speech and non-speech sounds in children with autism. *Brain Research* 1066, 147–157.

Lepistö, T., Silokallio, S., Nieminen-von Wendt, T., Alku, P., Näätänen, R., and Kujala, T. (2006). Auditory perception and attention as reflected by the brain event-related potentials in children with Asperger's syndrome. *Clinical Neurophysiology* 117, 2161-2171.

Levine, M., Carey, W., and Crocker, A. (1999). *Developmental-Behavioral Pediatrics*, 3rd Ed. Elsevier, Philadelphia, PA.

Messinger, D., Young, G., Ozonoff, S., Dobkins, K., Carter, A., Zwaigenbaum, L., Landa, R. J., Charman, T., Stone, W. L., Constantino, J. N., Hutman, T., Carver, L. J., Bryson, S., Iverson, J. M., Strauss, M.S., Rogers, S. J., and Sigman, M. (2013). Beyond autism: A baby siblings research consortium study of high-risk children at three years of age. *Journal of the American Academy of Child and Adolescent Psychiatry* 52, 300-308.

Ming, X., Brimacombe, M., and Wagner, G. (2007). Prevalence of motor impairment in autism spectrum disorders. *Brain Development* 29, 565-570.

Mostofsky, S., and Ewen, J. (2011). Altered connectivity and action model formation in autism is autism. *The Neuroscientist* 17, 437-448.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., and Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders* 36, 27-43.

Ozonoff, S., Young, G., Belding, A., Hill, M., Hutman, T., Johnson, S., Miller, M., Rogers, S. J., Schwichtenberg, A. J., Steinfeld, M., and Iosif, A. M. (2014). The broader autism phenotype in infancy: When does it emerge? J*ournal of the American Academy of Child and Adolescent Psychiatry* 53, 398-407.

Patten, E., Belardi, K., Baranek, G., Watson, L., Labban, J. D., and Oller, D. K. (2014). Vocal patterns in infants with autism spectrum disorder: Canonical babbling status and vocalization frequency. *Journal of Autism and Developmental Disorders* 44, 2413-2428. doi:10.1007/s10803-014-2047-4.

Paul, R., Chawarska, K., Fowler, C., Cicchetti, D., and Volkmar, F. (2007). "Listen my children and you shall hear": Auditory preferences in toddlers with autism spectrum disorders. *Journal of Speech, Language, and Hearing Research* 50, 1350-1364.

Paul, R., Fuerst, Y., Ramsay, G., Chawarska, K., and Klin, A. (2011). Out of the mouths of babes: vocal production in infant siblings of children with ASD. *Journal of Child Psychology and Psychiatry* 52, 588-598.

Plumb, A., and Wetherby, A. (2013). Vocalization development in toddlers with autism spectrum disorder. *Journal of Speech, Language, and Hearing Research* 56, 721-734.

Port, R. (2015). Technical committee report: Speech communication. *Acoustics Today* 11, 68-71.

Rapin, I. (1996). *Preschool Children with Inadequate Communication: Developmental Language Disorders, Autism, Low IQ*. Mac Keith Press, London.

Rapin, I. (2011). Autism turns 65: A neurologist's bird's eye view. In Geschwind, D., Dawson, G., and Amaral, D. (eds), *Autism Spectrum Disorders*. Oxford University Press, New York.

Rapin, I., Dunn, M., Allen, D., Stevens, M., and Fein D. (2009). Subtypes of language disorders in school-age children with autism. *Developmental Neuropsychology* 34, 66-84.

Rutter, M. (2013). Changing concepts and findings on autism. J*ournal of Autism and Developmental Disorders* 43, 1749-1757.

Schoen, E., Paul, R., and Chawarska, K. (2011). Phonology and vocal behavior in toddlers with autism spectrum disorders. *Autism Research* 4, 1-12.

Seery, A., Vogel-Farley, V., Tager-Flusberg, H., and Nelson, C. (2013). Atypical lateralization of ERP response to native and non-native speech in infants at risk for autism spectrum disorder. *Developmental Cognitive Neuroscience* 5, 10-24.

Shield, A., and Meier, R. P. (2013). The acquisition of sign language by deaf children with autism spectrum disorder. In Quinto-Pozos, D. (ed), *Multilingual Aspects of Signed Language Communication and Disorder,* Multilingual Matters, Bristol, UK, pp. 90-122.

Shriberg, L. D., and Kwiatkowski, J. (1994). Developmental phonological disorders I: A clinical profile. *Journal of Speech and Hearing Research* 37, 1100–1126.

Shriberg, L., Paul, R., Black, L., and van Santen, J. (2011). The hypothesis of apraxia of speech in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders* 41, 405-426.

Shriberg, L., Paul, R., McSweeny, J., Klin, A., Cohen, D. J., and Volkmar, F. R. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research* 44, 1097-1115.

Steigler, L. (2015). Examining the echolalia literature: Where do speech-language pathologists stand? *American Journal of Speech-Language Pathology* doi:10.1044/2015_AJSLP-14-0166.

Suskind, R. (2014). Life, *Animated. A Story of Sidekicks, Heroes, and Autism*. Kingswell, Glendale, CA.

Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders* 11, 45-56.

Talbott, M., Nelson, C., and Tager-Flusberg, H. (2013). Maternal gesture use and language development in infant siblings of children with autism spectrum disorder. *Journal of Autism and Developmental Disorders* doi:10.1007/s10803-013-1820-0.

Tierney, C., Mayes, S., Lohs, S., Black, A., Gisin, E., and Veglia, M. (2015). How valid is the checklist for autism spectrum disorder when a child has apraxia of speech? *Journal of Developmental and Behavioral Pediatrics.* doi:10.1097/DBP.0000000000000189.

Warlaumont, A., Richards, J., Gilkerson, J., and Oller, D. K. (2014). A social feedback loop for speech development and its reduction in autism. *Psychological Science* 25, 1314-1324. doi:10.1177/0956797614531023.

Wolf-Schein, E., Fisch, G., and Cohen, I. (1985). A study of the use of nonverbal systems in the differential diagnosis of autistic, mentally retarded, and fragile-X individuals. *American Journal of Dance Therapy* 8, 67-80.

Wong, C., Odom, S., Hume, K., Cox, A., Fettig, A., Kucharczyk, S., Brock, M. E., Plavnick, J. B., Fleury, V. P., and Schultz, T. R. (2015). Evidence-based practices for children, youth, and young adults with autism spectrum disorder: A comprehensive review. *Journal of Autism and Developmental Disorders* 45, 1951-1966.

Zoghbi, H. Y. (2003). Postnatal neurodevelopmental disorders: meeting at the synapse? *Science* 302, 826-830.

Zwaigenbaum, L., Bryon, S., and Garon, N. (2013). Early identification of autism spectrum disorders. *Behavioural Brain Research* 251, 133-146.