CHAPTER

17

Early Development of Speech and Language

Cognitive, Behavioral, and Neural Systems

H. Tager-Flusberg, A.M. Seery

Boston University, Boston, MA, USA

OUTLINE

17.1 INTRODUCTION

The acquisition of spoken language is one of the most remarkable and uniquely human accomplishments. At birth, newborns are capable of producing only cries and other vegetative sounds, have no control over their oral-vocal tract, and understand no meaningful speech. Within 3 years, without overt instruction, children have mastered the complex speech sound system of their language and acquired a rich and varied vocabulary. They have sufficient grammatical knowledge to allow them to talk about a wide range of topics, referring to events, people, and abstract ideas that are not immediately present in their environment and may exist only in their imaginations, thus going well beyond the communicative abilities of any other species. Human languages are highly complex, hierarchically organized abstract systems, composed of a phonological rule system specifying how speech sounds are combined, lexicon, syntax, morphology, and pragmatic and discourse rules. These systems depend on the development of a range of domain-specific and domain-general cognitive and

Neural Circuit Development and Function in the Brain: Comprehensive Developmental Neuroscience, Volume 3 http://dx.doi.org/10.1016/B978-0-12-397267-5.00148-5

neural mechanisms that interact and become integrated into organized functional networks over the course of the first few years of life. This chapter summarizes what is currently known about the early development of speech and language skills in typically developing children, beginning with the prenatal period and then addresses how these developmental processes may go awry in children with language disorders.

17.1.1 What Is Language?

Spoken languages are composed of sounds; phonemes are the minimal linguistic units of a language and include vowels and consonants. The rapidly changing acoustic properties of phonemes are free to vary across speakers, time, and context, which makes the problem of speech perception particularly challenging. On the production side, speech sounds involve highly complex and intricately timed sequences of movements from the lower to the upper respiratory tract, through the larynx and oral and nasal cavities, and involving the lips, tongue, teeth, and glottis to produce phonemes. Within each language, there are constraints, or rules, which specify the permissible sequences of phonemes, referred to as phonotactic constraints. In addition, speech involves prosodic features that characterize the stress patterns of words and sentences that may be influenced by lexical, grammatical, or pragmatic factors.

Phonemes are combined to create the minimal unit of a language that carries meaning (semantic function), referred to as morphemes. Words (or lexical items) make up the vast majority of a language's morphemes. Most languages also include a smaller set of morphemes called 'bound morphemes' because they are affixed to other morphemes but still carry meaning such as tense, mood, number, and gender. Examples in English include past tense (-*ed*), the negative *un-*, or the plural -*s*. In turn, words and morphemes are combined to create sentences. The rules governing the order and hierarchical organization of sentence structure make up the syntax of a language. Together, the phonology, morphology, semantics, and syntax form the structural components of language. The functional uses of language, or pragmatics, include a variety of speech acts (e.g., directive, question) as well as the social rules governing the use of language in a range of discourse contexts (e.g., conversation, narrative).

The neural bases of language perception and production are relatively well known (e.g., Hickock, 2009). Large networks of cortical and subcortical regions are involved, spanning basic sensory and motor systems to higher-order, relatively specialized cortical areas. In the majority of adults, in whom most *in vivo* studies have been carried out, these specialized areas, devoted primarily to linguistic processing, are functionally organized asymmetrically in the left hemisphere of the brain; the two most significant areas include Broca's area in the inferior frontal cortex and Wernicke's area in the temporal lobe. These regions are connected via white matter fiber bundles, including the primary dorsal pathway, the *arcuate fasciculus*, as well as secondary dorsal and ventral pathways (Friederici, 2009). Although less is known about the development of these neural systems because of limitations to the use of neuroimaging methods in infants and young children, there is now an emerging body of research focusing primarily on perceptual and language processing using electrophysiological methods, which are the most easily adapted for use with infants (Kuhl, 2010).

17.2 SPEECH PERCEPTION

Speech perception and language comprehension rely on complex neural networks that, in most adults, heavily involve the perisylvian region of the left hemisphere. Research has explored the early behavioral responses and neural correlates of exposure to language in neonates and infants to investigate the development of the language networks.

17.2.1 Prenatal Responses to Speech and Language

The auditory system is almost fully developed by the third trimester of pregnancy, so the developing fetus can process auditory and speech stimuli, although the rapid temporal features of phonemic stimuli are, for the most part, filtered out by the mother's body and uterine environment. Near-term fetuses show a more sustained heart rate deceleration to sentences than to music but do not differ in their response to sentences and chimeras of these sentences with all phonetic information removed (Granier-Deferre et al., 2010). Most prenatal exposure to phonemic stimuli is provided by the mother's voice, the vibrations of which are transmitted directly to the fetus.

Infants learn about many aspects of language during the last weeks of the prenatal period, including the identity of their mother's voice, stress patterns of the language, as well as specific segments of language (such as repeated passages from storybooks) to which they have been exposed. Beginning around 32 weeks' gestation, fetuses exhibit heart rate deceleration in response to recordings of their mother's voice (Kisilevsky and Hains, 2011), and near-term infants show differential patterns of heart rate response to recordings of the mother's voice and a stranger's voice (Kisilevsky et al., 2003). At birth, infants distinguish and prefer their own mother's voice over the voice of a female stranger (DeCasper and Fifer, 1980), speech passages they were exposed to prenatally over novel passages (DeCasper and Spence, 1986), and their native language over other rhythmically dissimilar languages (Byers-Heinlein et al., 2010; Mehler et al., 1988; Nazzi et al., 1998).

17.2.2 Newborn Speech Perception

From birth onward, infants display a strong preference for listening to speech over other auditory stimuli. Neonates exhibit more nonnutritive, high-amplitude sucking when rewarded with linguistic stimuli than with white noise (Butterfield and Siperstein, 1970), tones, or scrambled speech sounds (Vouloumanos and Werker, 2007). Even very young infants possess sophisticated speech perception abilities, which is similar to adults in a variety of ways.

Adults perceive phonetic information categorically. For instance, the speech sounds /da/ and /ta/ differ with respect to the phonetic feature of voice onset time (VOT), and when presented with syllables with VOTs varying continuously, adults perceive only two sounds: /*da*/ or /*ta*/. Furthermore, adults are easily able to extract phonetic information despite the fact that the acoustic properties of speech vary drastically depending on the individual speaker's voice. Behavioral studies have found that 2-month-old infants detect phonetic changes regardless of whether this change is accompanied by a change in pitch (Kuhl and Miller, 1982) or speaker (Jusczyk et al., 1992). In newborns, electrophysiological studies have shown that the neonatal brain responds as quickly to a change in phonemic category whether or not this is accompanied by a change of speaker (Dehaene-Lambertz and Pena, 2001). Neonates extract linguistically relevant phonemic information from the extraneous acoustic information related to specific voices and thus normalize across speakers. Notably, however, this is not due to an inability of infants to discern the different voices as neonates have been shown to discriminate at least between male and female voices (Floccia et al., 2000). In addition to normalizing across speakers, very young infants, like adults, perceive speech sounds categorically rather than continuously. Infants will dishabituate more to a change in syllable when this change crosses adult categorical boundaries than when the change occurs within a given phonetic category (Eimas et al., 1971). Newborns are sensitive to linguistic or auditory 'gestalts,' such as syllable repetition. Specifically, they show increased response over the temporal and left frontal areas to grammars containing a consecutive repetition (ABB sequences, e.g., 'mubaba'), suggesting the possibility of automatic perceptual detection of auditory repetition (Gervain et al., 2008).

17.2.3 Development of Speech Perception

After birth, infants continue to learn about the language that they are exposed to, and by 4 months, infants discriminate their own language even from other very similar languages, such as Spanish and Catalan (Bosch and Sebastián-Gallés, 2001). Infants also undergo a drastic transition where their perception of speech becomes shaped by exposure to a specific language. Each language contrastively uses only subsets of the available universal phonetic categories, and adults cannot easily discriminate between phonetic categories not used in their native language.

Infants are prepared to perceive any language they might encounter but gradually restrict this ability to their own language over the first year of life through a process of perceptual narrowing. Infants stop discriminating consonant contrasts not used in their native language by around 10 months of age (Werker and Tees, 1984). Measuring electrophysiological response to a phonetic change after a repeated syllable has shown that this perceptual narrowing involves decreased response when the change involves nonnative phonemes (Cheour et al., 1998; Rivera-Gaxiola et al., 2005) coupled with increased response when the change involves native-language phonemes (Rivera-Gaxiola et al., 2005), suggesting a process of neural commitment to native-language phonemes (Kuhl, 2004). A similar study using near-infrared spectroscopy, which is more sensitive than electrophysiology to spatial localization of neural processing, found that increased response to native phoneme changes did not stabilize until around 10 months of age, and a left-lateralized response to native-language phonemes emerged around 13 months of age (Minagawa-Kawai et al., 2007).

Using magnetoencephalography, Imada and colleagues found that a wide range of sounds, including speech, elicited responses in left hemisphere superior temporal areas in infants from birth through 12 months of age (Imada et al., 2006). In contrast, inferior frontal areas of the left hemisphere were not responsive to speech until after age 6 months; this response was correlated with temporal region responses to speech by 12 months of age, suggesting the basic neural network for processing language is in place by the end of the first year. It may be that there are structural predispositions for these functional networks to develop in the left hemisphere (Dubois et al., 2009).

In sum, it is evident that the infant brain possesses some degree of functional organization of the language networks present in human adults. The superior temporal region, in particular, responds to language at birth, although this response is not specific to speech. To some extent, left-lateralized responses may be driven by acoustic characteristics of the auditory stimulus in addition to truly linguistic properties. Although there are some inconsistencies in the current infant literature, which may be the result of different experimental paradigms and stimuli as well as imaging modality, by the end of the first year, the neural and cognitive bases for speech perception appear to be firmly in place in perisylvian regions of the left hemisphere.

17.3 SPEECH PRODUCTION

In contrast to the perception of speech, at birth, infants are not able to produce any speech-like sounds. This capacity develops over the course of the first year of life and continues as the child's developing phonological system is acquired alongside other aspects of language development.

17.3.1 Infant Speech Production

The developmental progression in speech production follows universal pathways. During the first 2 months of life, infants produce a range of reflexive vocalizations that appear to be automatic responses to their physical state. These include crying, fussing, and vegetative sounds. The range of sounds produced by very young infants is constrained by the size of their oral cavity and the position of the larynx (Lieberman et al., 1972). Between 2 and 4 months, there are still significant limitations to the infant's ability to articulate, but the vocal repertoire expands to include pleasure-related cooing sounds. These sounds, which may include some vowels or consonants, are produced in the back of the mouth with articulation limited to movements of the jaw (Kent, 1999).

Beginning at around 4 months, as developmental changes take place in the morphology of the vocal tract, infants engage in more vocal play that includes both nonspeech and speech sounds such as rudimentary vowels and consonants. At 6 months, babbling begins, with the infant producing well-formed consonant–vowel (CV) syllables that now extend to those involving movements of the lips and tongue. Canonical babbling (repeated sequences of CV syllables) is viewed as the most significant milestone in speech production (Oller, 2000). During the latter half of the first year, the infant's sound combinations become increasingly more variable and frequent, though there appears to be a relatively small set of consonants produced across infants acquiring many different languages (Locke, 1983). As infants move closer to the onset of meaningful speech, their babbles increase in length and incorporate varied stress and intonation patterns, often referred to as 'jargon' or conversational babble.

The development of speech motor control plays an important role in speech sound production. A computational model of this process was introduced by Guenther (1995). According to this self-organizing model, the initiation of speech is the product of the perception of intended target sounds. Thus, auditory feedback from both adult and self-produced speech is critical in developing the mapping between target sounds and developmental changes in the vocal tract. On this view, there is a close link between the development of speech perception and production, which is consistent with the finding that although deaf infants produce early vocalizations, they rarely engage in canonical babbling and their sound production lessens over time (Stoel-Gammon, 1998).

17.3.2 Relationship Between Speech and Motor Developments

During the first year of life, infants not only develop the ability to articulate complex speech sounds, they also make significant advances in other aspects of motor development. While there are parallels between speech and motor developments, the relationship between them is both complex and quite specific. Gross motor milestones are not closely tied to developmental stages in babbling; however, it has been found that rhythmic arm banging, with or without objects, consistently emerges just prior to the onset of canonical babbling (Iverson and Thelen, 1999). Iverson (2010) argues that these repetitive hand movements provide opportunities for practicing skills required for canonical babbling as they both involve rhythmically organized motor stereotypies.

Babbling begins as a behavior tied closely to the speech motor system, offering the opportunity to practice complex articulatory movements in the context of proprioceptive and auditory feedback. Over time, babbling rapidly becomes integrated with other developmental changes and events in the environment to emerge as an early linguistic skill (Iverson, 2010). The close neural links between brain regions involved in language and motor behavior provide support for the view that there are reciprocal influences between these systems over the course of development, with the onset of intentional communication in infants evident in manual and other body gestures (Iverson et al., 2007).

17.3.3 Phonological Development

It is generally agreed that there is essential continuity between prelinguistic babbling and the earliest stages of phonological development evidenced in the child's first words (Stoel-Gammon, 1998). The majority of sounds produced in the earliest words of children are the same as those preferred in their babbles. Initially, children's words are composed of simple CV syllable structures, using a relatively small inventory of sounds. Gradually, over time and with growth in vocabulary, there is an expansion in the range of sounds produced by children. Although there is no universal order in the acquisition of phonological features, certain regularities have been found in the phonological sounds that are used across children, reflecting developmental changes in the vocal tract (Stoel-Gammon and Sosa, 2007). Mastery over vowels occurs before that over consonants. The main consonant classes that are used earlier in development include stops (e.g., *b*, *d*), nasals (e.g., *m*, *n*), and glides (e.g., *w*). Later developing consonants include fricatives (e.g., *v*) and liquids (e.g., *l, r*).

As children begin producing more elaborate syllable structures and a wider range of sounds in words, they begin making speech sound errors. The most striking feature of these errors is that while there are individual differences in the particular kinds of errors made, the errors are not random, but instead fall into common patterns, reflecting developmental changes in the child's representation of the speech sound system (Grunwell, 1981; Ingram, 1976). In children with more severe articulation difficulties, words may be produced that involve combinations of different error patterns, but in most children, speech sound errors do not persist beyond the preschool years.

Young children will often omit syllables or specific sounds as they attempt to reproduce more complex adult words (Menn and Stoel-Gammon, 2009). Typically, unstressed syllables will be omitted; those occurring at the beginning of words (e.g., *mato* for *tomato*) or in the unstressed medial position (e.g., *e'phant* for *elephant*), and consonant clusters often lead to omissions (e.g., *top* for *stop*). Another class of error patterns is to change sounds at the level of individual articulatory features. For example, voiced consonants may be changed to unvoiced consonants (e.g., *bot* for *pot*). Place changes also may be found in some children, with back consonants becoming more frontal (e.g., *dame* for *game*). These kinds of errors demonstrate the significance of features in children's phonological representations. A third class of errors illustrates how the child's representation of the target word may influence the kinds of sound substitutions that are made. Assimilation errors entail the change in one sound in the target word to make it more similar to another sound in that word. Such errors may involve assimilation in different feature classes such as voicing (e.g., *doad* for *toad*) or place (*gog* for *dog*).

Several theoretical frameworks have been proposed to account for the acquisition of phonology, but the most promising current formal model is optimality theory (Archangeli and Langendoen, 1997). On this model, representations of phonological inputs are evaluated against a set of finite and universal constraints to determine an optimal output phonological form. Here, the notion of constraints replaces earlier theories that defined absolute, serially applied abstract rules. Within optimality theory, constraints are not absolute but operate in parallel in a language-specific order. Optimality theory has been shown to be highly successful in capturing children's phonological error patterns as well as variation found between, and within, individual children acquiring different languages (Barlow and Geirut, 1999).

17.4 SOCIAL–COGNITIVE FOUNDATIONS OF LANGUAGE

Language is a cultural system, acquired within the context of specific environments and embedded in the emergence of developments in the child's cognitive, emotional, and social capacities. Thus, language is the vehicle that satisfies the child's motivation to engage and communicate with social partners. In the absence of any social partners, for example, in children raised in complete isolation, language is not acquired (cf. Curtiss, 1977).

17.4.1 Social Engagement

From birth, the social niche for language is clearly established in the infant's preference for human voices and faces. Over the first few months of life, rapid changes take place. Mothers and their infants begin to interact in finely tuned ways with one another. They synchronize their eye gaze, movements, and facial expressions of affect in patterns that resemble turn-taking patterns in conversations (Snow, 1977). By the age of 4 months, there is a marked increase in vocal turn-taking during these rich interactions between infants and their caretakers (Ratner and Bruner, 1978). Thus, engagement with other people provides the context that lays the groundwork for infants' motivation to communicate. Interestingly, the neural foundations for these social capacities are available very early in the first year of life (Grossmann and Farroni, 2009).

17.4.2 Infant-Directed Talk

In their interactions with infants, adults in most cultures speak in a special register, including a higher pitch, more variable intonation patterns, and shorter utterances that focus on objects and people in the immediate environment (Fernald, 1989). This register, now referred to as 'infant-directed talk' (IDT), is strongly preferred by infants (e.g., Werker and McLeod, 1989). Its properties capture infants' attention and facilitate the analysis of the phonological properties and statistical regularities of their native language (Burnham et al., 2002; Thiessen et al., 2005). Together, these features serve to facilitate the acquisition of the formal features of language as well as the child's ability to learn the meanings of words toward the end of the first year (Waxman, 2003).

IDT also incorporates rich emotional content captured in the prosodic contours that convey different emotional states. Younger infants are very sensitive to this component of IDT and respond to IDT statements of approval and praise with higher rates of smiling and attention even when they hear adults speaking in a different language (Fernald, 1989). Together, the features of IDT ensure that infants attend to the speech and language in their environment and facilitate the processing of its essential features and characteristics.

17.4.3 Intentional Communication

Toward the end of the first year of life, vocalizations as well as other nonvocal behaviors become genuinely integrated into social interaction as infants' developing social–cognitive capacities lead to the onset of intentional communication (Carpenter et al., 1998). At this point, infants become capable of coordinating their attention to objects or events with other people through eye gaze patterns (joint attention), gestures, and vocalizations. This developmental achievement is generally viewed as a critical step in language acquisition, with the onset of communicative intent. Infants at this stage are able to communicate a variety of meanings, including *protodeclaratives*, which involve pointing or other gestures to draw another person's attention to objects of interest, and *protoimperatives*, gestures or vocalizations to express requests for objects or actions. The significance of these communicative attempts is that they indicate the infant's capacity to understand the intentions of others (the beginning of a theory of mind), at least in a rudimentary or implicit form (Tomasello, 1999).

Infants' preverbal communications go beyond pointing to encompass other conventional gestures such as nodding or shaking their head to signify acceptance or rejection, waving as a salutation, or invented gestures that may incorporate symbolic features of an object or event, such as wiggling a finger to refer to a dog (Carter, 1979). Gestural communication is an important predictor of spoken language development in children and is another example of the close developmental links between the motor and linguistic systems (Rowe and Goldin-Meadow, 2009).

17.4.4 Pragmatic Development

As children begin to speak, their utterances express the same functions as their early preverbal gestural forms. By the time children are three, new functions emerge, including the use of language to describe objects or events, or to assert an opinion, for example, and they employ a range of conversational devices. At this point, children are able to express each of these functions using a variety of linguistic forms. The development of functional and communicative aspects of language is closely tied to developments in theory of mind and related social–cognitive achievements (Bartsch and Wellman, 1995).

There is a more protracted period of development for expressing functions using more indirect forms, such as indirect requests. Although 2-year-olds use terms such as *want* or *need* as a way of asking for something (e.g., *I need new ball*), genuine indirect requests do not emerge until around the age of three (e.g., *Where is the truck?*). By three years of age, children can use polite forms to make their request (e.g., *Would you give me a cookie?*), but hints or oblique indirect requests are not used until the early school years (Bryant, 2009).

Research has focused on children's developing awareness of the effect of their speech on a listener by taking into account the listener's knowledge. For example, 4-year-olds change the way they speak depending on their audience; thus, they use simpler language if they are talking to 2-year-olds compared to their language addressed to older children or adults. These modifications in children's discourse show some awareness of the distinct needs of a very young conversational partner (Shatz and Gelman, 1973).

Communicative competence entails knowing how to engage in conversations in appropriate and informative ways. Ultimately, this depends on appreciating both literal and nonliteral uses of language (e.g., metaphor, irony, and white lies), but these developments continue well into middle childhood (Siegal and Surian, 2007). Children also must master a range of different forms of discourse from conversation, to personal narratives to storytelling. The use of language in various contexts provides the interactive, communicative framework within which children acquire knowledge of the linguistic structures available in their native language so that they can express more fully the ideas that are generated by their developing cognitive and social systems.

17.5 LEXICAL DEVELOPMENT

By the end of the first year, infants already understand a number of words and phrases and soon begin to produce words. This is a critical milestone that is often used as an objective proxy for the onset of language. Long before this milestone is reached, infants have acquired the skill of segmenting words within streams of continuous speech where there are often no clear boundaries, using a variety of cues, including sequential statistical information (Saffran et al., 1996) and consistent stress patterns (Jusczyk et al., 1999).

17.5.1 Stages of Lexical Development

Lexical development can be divided into three broad periods. The first covers the acquisition of the initial 50 words or so, during which children are learning what words do. At this stage, some words appear to be tied to particular contexts and serve primarily social or pragmatic purposes. Word learning during this initial phase is relatively slow and uneven (Nelson, 1981). The child's vocabulary at this stage, especially in Western middle-class children, is dominated by names for objects, including animals, people, toys, and familiar household things. Other early words include social terms (e.g., *hi*, *bye*), modifiers (e.g., *more*, *wet*), and relational terms that express success, failure, recurrence, direction, and so forth (Bates et al., 1994).

By the middle of the second year, there is a significant increase in the rate at which children acquire new words. This new period is usually referred to as the vocabulary spurt and may be punctuated by requests from children for adults to label things in the world around them. Words are learned very quickly, often after only a single exposure that may take place without any explicit instruction (Tomasello, 2003). This process of rapid word learning is referred to as *fast mapping* (Houston-Price et al., 2005).

By the time children reach their third birthday, they begin to develop a more organized lexicon, in which the meaning relations among groups of words are discovered. For example, at this time, children begin to learn words from a semantic domain, such as kinship, and they are able to organize the words according to their similarities and differences in dimensions of meanings (Nagy and Scott, 2000). For nouns labeling concrete objects, children begin to organize taxonomies, now also learning words at the superordinate and subordinate levels and understanding the hierarchical relations among terms such as dachshund, dog, and animal. Semantic developments at this stage will often lead to reorganizational processes as these kinds of relationships among words are realized by the child (Bowerman, 1978). The rate of word learning continues to be very rapid with estimates suggesting that children acquire about 15–20 new words a day during the preschool years and beyond (Bloom, 2000).

17.5.2 Developmental Processes

How do children accomplish the challenge of acquiring arbitrary symbols and their associated sound forms (words) to communicate concepts so rapidly? Research has identified several factors that facilitate the task of word learning in young children. At the most transparent level, the input to children provides one critical constraint on the words they acquire. The number and frequency of specific words in parents' speech to children correlates significantly with the frequency of those words in the children's vocabulary (Huttenlocher et al., 1991), and these variables correlate with socioeconomic status, reflecting the fact that more highly educated mothers speak far more to their children than mothers with little education (Hoff, 2006). The social context of word learning also helps young children who, because of their ability to infer intentions, can map word meanings by observing where their mother is looking or what she is pointing at when she labels objects (Baldwin and Meyer, 2007).

The child's developing conceptual knowledge influences the meanings they map onto words (Bloom, 2000). The relationship between language and conceptual development, or more generally between language and thought, is highly complex with each system placing constraints on the other, and with both being dependent on the social environment for their elaboration in development. Other general cognitive processes, including attention and memory, are also clearly important in word learning (Samuelson and Smith, 2000).

Children bring to the task of word learning several constraints that guide their hypotheses about the possible meanings of words. Markman (1989) has proposed that young children rely on three primary constraints including the *mutual exclusivity constraint*, which leads the child to assume that each object only has a single name and that a name can only refer to one category of objects; the *whole-object constraint*, which states that new words refer to whole objects rather than parts of objects; and the *taxonomic constraint*, which states that words refer to categories of objects (not specific exemplars). While some view these kinds of constraints as principles that are specific to lexical development, others view them as more general biases that may be an aspect of broader pragmatic or cognitive processes (Diesendruck, 2007).

Lexical development takes place in parallel with other aspects of language, particularly the acquisition of syntactic knowledge. Children use syntactic information to facilitate word learning, especially when other cues are not available, as is often the case for learning the meanings of related verbs such as *look* and *see*. In cases such as this, children can use information about the number and kind of arguments that occur with particular verbs to work out their meanings (Naigles and

Swensen, 2007). Thus, transitive verbs take object arguments while intransitive verbs do not. Syntactic information is also useful for figuring out the distinction between mass nouns (e.g., *spaghetti*) from count nouns (e.g., *a potato*), or between common nouns and proper names, and very young children have been shown to use this information when they hear new words in ambiguous contexts (Hall and Waxman, 2004).

Children depend on a wide range of cognitive, social, and linguistic mechanisms to learn the meanings of new words, and the input provided by their conversational partners helps to guide and constrain the learning process. Several integrative theoretical models have been proposed to account for how children might attend to different types of cues at different developmental stages and weigh the information carried by competing cues to lexical meaning (Bloom, 2000; Hollich et al., 2000). Such models have the potential to account for individual differences in, for example, children learning different languages or raised in different kinds of learning environments. A number of computational models of early word learning have been developed (e.g., Frank et al., 2009), though thus far, none has incorporated the full range of processes or constraints that are central to these integrative developmental models.

17.5.3 Neural Bases of Word Learning

By 5 months of age, infants' neural response shows sensitivity to the word stress patterns used in their language and will show a mismatch event related potential (ERP) response to deviations from this stress pattern (Weber et al., 2004). By 10 months, infants show distinct patterns of brain activity in response to familiar two-syllable words embedded in continuous speech, even when they have previously heard the word only in isolation (Kooijman et al., 2005).

As infants become more verbal, experience with language influences the organization of their neural response, resulting in distinct patterns of brain activity in response to words that an infant understands by 11 months (Thierry et al., 2003). Between 13 and 17 months, infants exhibit a broadly distributed bilateral response to words in general and a stronger N200 response to words that are understood than to words that are not (Mills et al., 1997). By 20 months, this pattern of response is localized to temporal and parietal electrode sites over the left hemisphere (Mills et al., 1993). The lateralized and focal response to known versus unknown words is linked more closely to linguistic ability rather than simply developmental maturation of the brain or brain connectivity. Thus, 13- to 17-month-old infants with more advanced receptive language skills showed a more localized neural response, whereas infants with low receptive language showed a less mature broader response pattern. One study with 20-month-old infants used a training paradigm to teach new words to label pictures of objects. After the training, there was an increased N200 response to the trained words over anterior electrode sites. This change in N200 response was independent of expressive vocabulary size, highlighting the influence of experience with a particular word and its meaning, not simply the infants' maturational level or overall language ability (Mills et al., 2005). Still, developmental maturation of language areas may influence the latency of response to new words as it decreases with age independent of language level (Mills et al., 1997).

In infants, semantic knowledge of word meaning is captured by a later negative response similar to the adult N400, which processes the integration of word meaning in context and involves the middle and superior temporal gyri (Kutas and Federmeier, 2011). In 19-month-old infants, the N400 response is elicited when shown pictures of objects paired with incongruent verbal labels (Friedrich and Friederici, 2004). Response to incongruent picture–word pairings is present early in the waveform over lateral frontal electrode sites, but is largest later in the waveform over both posterior and frontal sites. This later N400 was stronger, earlier, and more similar to that of adults in infants with more advanced receptive vocabularies. At 19 months, robust N400 responses are also elicited in priming contexts in the majority of infants. At 12 months, infants with advanced productive vocabularies also show an N400 response to priming, though at this early age, it is slightly delayed in onset and smaller in duration than in older children or adults (Friedrich and Friederici, 2010). The early functioning of N400 neural mechanisms highlights their significance for word learning, though the precise nature of this relationship is not yet known.

17.6 SYNTACTIC DEVELOPMENT

By the time they are 2 years old, toddlers begin combining words to form two or three word phrases or primitive sentences. From the earliest stages, children demonstrate their sensitivity to some of the basic rule-governed properties of their target language, for example, word order rules in English, though the precise nature of the knowledge this represents is still hotly debated.

17.6.1 Stages of Syntactic Development

Children must segment the sound stream they hear into morphemes, phrases, and sentences (Morgan, 1986) and discover word classes (nouns, verbs, determiners, etc.) because grammatical rules operate on these more abstract categories to create hierarchically organized sentences. They must also figure out if their target language encodes tense, person, number, etc., and if so, whether these are marked by grammatical morphemes or other linguistic means. Different theories have been proposed for how children acquire this knowledge, ranging from distributional statistical (e.g., Mintz et al., 2002), to functional (Tomasello, 2002), to semantic bootstrapping (Pinker, 1984), to linguistic nativist approaches (Chomsky, 1995).

Across different languages, children begin by building phrasal units (e.g., noun phrase), move on to simple sentence structures and different sentence modalities (e.g., statements, questions), and finally master complex sentences such as coordinations and embeddings. As children's grammatical development proceeds, the length of their utterances increases, reflecting both the acquisition of linguistic knowledge (Brown, 1973) and growth in general cognitive capacities, particularly verbal working memory.

17.6.2 Early Sentences

As early as 18 months of age, the hierarchical nature of phrasal structures (e.g., *the red barn*) is available to children (Lidz et al., 2003). At this stage, English-speaking children adhere closely to using word order in their productive speech but omit most grammatical morphemes that mark, for example, tense or number. In contrast, children acquiring inflectionally rich languages such as Italian or Hebrew use the morphemes marking these features even in their very early productions (Caselli et al., 1999; Levy, 1988).

Children's early 'sentences' express a universal set of meanings: they talk about objects and people present in the environment, their locations, attributes, and interrelationships (Brown, 1973). Often their sentences will omit the subject, and while children acquiring languages where subjects are obligatory do so less than children acquiring languages in which so-called null subjects can be grammatical (Valian, 1990), these omissions reflect the limited cognitive capacity of young children and the fact that sentence subjects may be inferred from the context and are therefore pragmatically not necessary (O'Grady et al., 1989).

17.6.3 Grammatical Morphology

In contrast to many other languages, English has a relatively impoverished set of affixes and lexical terms that comprise its grammatical morphology to mark tense, number, person, etc. The course of development is thus a gradual process that is quite protracted, though across children, there is a similar order in which different morphemes are acquired reflecting their linguistic complexity. The developmental process is more rapid in languages such as Italian, though within each language, there is still a constrained order in which different morphemes are mastered (Brown, 1973).

In English, there are both regular and irregular forms to mark, for example, tense (e.g., *walk–walked*; *run–ran*) or number (e.g., *boy–boys*; *mouse–mice*). As children acquire these morphemes, they go through a stage of making errors, particularly by providing regular affixes to irregular verbs or nouns (e.g., *runned*; *mouses*). Pinker and his colleagues (Pinker, 1999; Ullman, 2001) argue that the acquisition and use of these different forms reflect two distinct mechanisms: a rule-learning system for regular forms and a lexical-memory system for irregular forms. In contrast, some computational models have been developed that can acquire the different forms based on a unitary mechanism that operates on the distributional properties of lexical items in the input (McClelland and Patterson, 2002).

17.6.4 Later Grammatical Development

Children's early utterances may be used to express a range of functions including statements, questions, and negations; however, they rely on single words or intonation to do so. By the preschool years, children acquire auxiliary verbs (do, be), and their negations and questions include the requisite verb morphology and inversion needed for questions (de Villiers et al., 1990). Sentences are now combined to create longer and more complex coordinated structures using '*and*' and later, '*if*,' '*because*,' and other coordinating conjunctions. Rarer complex linguistic constructions, for example, relative clauses, or the passive form are not mastered until the early school-age years. The order and speed of syntactic development reflect both the frequency of forms in the input and the complexity of the abstract rules that underlie them (Tager-Flusberg and Zukowski, 2009).

17.6.5 Neural Bases of Grammatical Development

In comparison to research on the neural bases of speech perception and word learning, few studies have been conducted on early grammatical development, perhaps reflecting the relative difficulty of obtaining reliable data from preschoolers who are less tolerant of electrode caps or sitting still. In adults, the most widely studied ERP components are an early left anterior negativity (ELAN), which is related to automatic sentence parsing based on word-category information or morphological violations and is thought to be generated in the left inferior frontal gyrus and anterior superior temporal gyrus (STG; Friederici et al., 2000). Later, and more controlled, syntactic processing occurs with a later positivity, the P600, during which syntax is integrated with other information and sentence reanalysis occurs in the context of syntactic anomalies or ambiguities (Kaan and Swaab, 2003).

By around 30 months, the ERP responses of toddlers to syntactic violations show a large, late positivity similar to the P600 (Bernal et al., 2010; Silva Pereyra et al., 2005) and, in some cases, display an earlier left-lateralized negativity similar to the adult ELAN (Bernal, et al., 2010). This similarity in waveform topography and morphology suggests that toddlers have already developed or constructed a relatively adult-like system for processing the syntax of simple sentences, including to some extent a system of automatic processing. Passive sentences, on the other hand, involve higher processing demands than do active sentences and do not evoke adult-like automatic components until late childhood or adolescence (Hahne et al., 2004).

Nevertheless, the neural response to syntactic violations is immature in children in that it is not yet functionally specified the way it is in adults. For example, functional magnetic resonance imaging (MRI) studies in adults show that distinct areas of the inferior frontal gyrus and STG are activated in response to syntactic violations versus semantic violations, particularly as processing demands increase. At the age of five or six, children still show substantial overlap in their fMRI activation to syntactic and semantic violations, particularly in the STG (Brauer and Friederici, 2007). These findings provide some support for the view that the acquisition of syntactic structure may be closely linked to semantics in young children.

17.7 LANGUAGE DISORDERS

The vast majority of children follow the developmental pathway to language described in the previous sections. But for some children, the onset of language is quite delayed; thereafter, the rate of development may be slowed, and the normal synchrony between the structural and pragmatic components of language may not hold. Children whose language is significantly delayed may never reach the same endpoints as typically developing children; this is especially true for those who also have intellectual disability, for example, children with known genetic syndromes including Down syndrome or fragile X syndrome (Tager-Flusberg, 2007). Limits in the acquisition of language beyond the early school years, specifically in the domains of syntax and morphology, have been taken as evidence for a critical period (e.g., Lenneberg, 1967).

Two complex neurodevelopmental disorders are defined, in part, on the basis of primary impairments in language and communication: specific language impairment (SLI) and autism spectrum disorder (ASD). SLI is diagnosed on the basis of delays and slowed rate of development of language in the absence of hearing impairment, frank neurological damage, social deprivation, or other neurodevelopmental disorders. ASD is diagnosed on the basis of impairments in communication, social reciprocity, and restricted or repetitive behaviors and interests. The majority of children with ASD also have comorbid impairments in structural aspects of language, and there is a growing interest in the overlap between ASD and SLI in their language phenotypes as well as genetic risk factors (e.g., Abrahams and Geschwind, 2008; Tager-Flusberg, 2004; Tager-Flusberg et al., 2008). A selective review of what is currently known about the developmental course and neurocognitive bases of language impairment in young children with these disorders, both of which are marked by significant heterogeneity in the severity and characterization of core and associated symptoms, is presented here.

17.7.1 Speech Perception

SLI and ASD are not diagnosed until the preschool years; however, in recent years, research has focused on infants at risk for these disorders, defined usually on the basis of family risk (e.g., presence of older sibling or other first-degree relative with the disorder), in order to capture the earliest emergence of deviations from patterns of normal development. Studies of 2-month-old infants at risk for SLI show significant differences in ERP responses for discriminating between long versus short syllable lengths (Friederici, 2006), and by 4–5 months, they show a reduced ERP response for discriminating the stress pattern of two-syllable words (Weber et al., 2004), suggesting that deficits in processing speech duration very early in life may be a marker for later language impairment. At 6 months of age, infants at risk for SLI are less able to discriminate tones presented in rapid succession, and the amplitude of the N250 mismatch ERP response is smaller and delayed in onset when listening to tones with brief interstimulus intervals (Benasich et al., 2006). These ERP measures predicted to language outcomes at the age of two. Taken together, these studies suggest that differences, which may affect auditory as well as speech perception, are present very early in life for infants at risk for SLI. Similar studies have not yet been carried out with infants at risk for ASD.

17.7.2 Speech Production

Retrospective reports highlight delays in the onset of babbling in children with SLI and ASD (Norbury et al., 2008; Tager-Flusberg et al., 2005). Children with ASD who have more severe deficits in acquiring spoken language also have a history of deficits in a range of other oral-motor skills (Gernsbacher et al., 2008). Prospective studies of infants at risk for ASD have confirmed that babbling is delayed in this group: between 6 and 12 months, infants at risk have fewer speech vocalizations and produce fewer consonants and less canonical babble (Paul et al., 2010). In addition, there is not as close a connection between the onset of babbling and rhythmic arm banging in high-risk infants as in typical infants (Iverson and Wozniak, 2007).

When children with SLI begin speaking, they are at higher risk for articulation disorders: though these are distinct syndromes, there is some overlap between SLI and speech sound disorders (Sices et al., 2007). Most children with ASD do not have impaired articulation (Kjelgaard and Tager-Flusberg, 2001), and their order of acquiring consonants follows the normal pattern (McCleery et al., 2006). Nevertheless, there is a group of children with more severe ASD (and often comorbid intellectual disability) who remain without spoken language and minimal vocal and speech repertoires despite years of intervention. It is not known what mechanisms are impaired in these children.

17.7.3 Social–Cognitive Foundations of Language

Relatively little research has focused on the early social development of children with SLI. Given that these children do not have primary social impairments, communicative and pragmatic aspects of language are less likely to be affected. There is some evidence that children with SLI may use more nonverbal communicative signals, particularly gestures, to compensate for their limited expressive language skills (Iverson and Braddock, 2011).

In contrast, given their primary impairments in social reciprocity, children with ASD have been extensively studied for the social–cognitive foundations of language. Infants at risk for ASD who later receive a diagnosis show significant declines in social engagement (eye contact, social smiling) beginning around 12 months (Ozonoff et al., 2010); they also produce significantly fewer gestures and do not respond to their name (Landa et al., 2007; Nadig et al., 2007). Early indicators of social cognition, including joint attention, imitation, and gestural communication, are all strongly correlated with language development in toddlers with ASD (Luyster et al., 2008), highlighting the ties between these domains.

Unlike typically developing children, most preschoolers with ASD show no preference for IDT, even their own mothers' IDT, over nonspeech analogs or other environmental sounds (Klin, 1991; Kuhl et al., 2005). A stronger preference for nonspeech sounds was associated with a lack of ERP response to differentiating speech sounds in a mismatch negativity paradigm and with more severe impairments in language development (Kuhl et al., 2005).

When they do begin speaking, children with ASD use a restricted range of functions, failing to use language in prosocial ways, such as directing attention to an object of interest, or exchanging thoughts and experiences (Wetherby et al., 2007). They have poor conversational skills, which is associated with deficits in theory of mind (Hale and Tager-Flusberg, 2005), and other discourse genres, including narration and storytelling, are also impaired when compared to children at the same language level (e.g., Diehl et al., 2006; Losh and Capps, 2003). Even children with ASD who have intact structural language skills continue to struggle with interpreting nonliteral uses of language, such as lies or metaphors, and show subtle deficits in integrating verbal and nonverbal (prosody, gesture, and eye gaze) modalities when communicating in face-to-face interactions (Tager-Flusberg et al., 2011).

17.7.4 Lexical Development

Children with SLI and ASD do acquire words, though usually at a slower rate. Among children with SLI, vocabulary size has been linked to the ability to accurately repeat multisyllabic nonsense words (e.g., Ellis Weismer et al., 2000). Nonword repetition provides a sensitive measure of phonological working memory, which is an important component of learning to map novel sound sequences to meaning. Children with ASD and comorbid language impairment also show impairments in nonword repetition (Kjelgaard and Tager-Flusberg, 2001).

Researchers have investigated whether children with language disorders are able to use the full range of processes and constraints to guide their acquisition of new words. Young children with SLI are less able to acquire new words using fast mapping (Rice et al., 1994) and are especially vulnerable when using syntactic cues (Rice et al., 2000). Studies of children with ASD have shown that they are able to use the mutual exclusivity constraint (e.g., Preissler and Carey, 2005), but they are less sensitive to social cues for word learning such as direction of eye gaze that signals a speaker's intention (Parish-Morris et al., 2007).

Toddlers who were later significantly delayed in language milestones showing signs of SLI did not exhibit the expected N400 ERP response for lexical-semantic processing in a picture–word matching paradigm at either 14 or 19 months (Friedrich and Friederici, 2005). Even older children with SLI only show a P600 response (but no N400) in response to semantic violations in sentence contexts. These differences in neural response suggest weaker lexical-semantic representations (Friederici, 2006).

17.7.5 Syntactic Development

There is general agreement that language disorders involve more serious impairments in syntax and morphology, compared to phonological or lexical development (e.g., Tager-Flusberg, 2007; Tomblin and Zhang, 1999). Children with SLI begin combining words to form simple utterances at least 2 years later than typical children, though they show the same general developmental trajectory in the growth of sentences over time (Rice, 2007). Children with ASD are also delayed, though there is far greater heterogeneity in both the onset of word combinations and rate of development in this population (Tager-Flusberg et al., 1990).

Rice (2007) has argued that SLI is characterized by primary deficits in the acquisition of particular aspects of grammar: those related to the morphology and syntax of tense, agreement, and case marking. For example, children with SLI go through a more protracted developmental period of omitting past or present tense morphemes (Rice et al., 1998). Children with ASD who have impairments in structural language also omit tense morphemes (Roberts et al., 2004), underscoring the parallels between these disorders. While Rice and her colleagues argue that these tense-marking deficits can be explained on the basis of disruptions in the acquisition of linguistic knowledge, others argue that they reflect domain-general processing limitations (e.g., Leonard et al., 1997).

A number of studies have investigated neural responses to different aspects of syntax in children with SLI. An early study found that lexicalized grammatical morphemes (function words), but not content words, elicited a more bilateral or even right-lateralized negativity, in contrast to the LAN evoked in typical children (Neville et al., 1993). Van der Leley (2005) investigated ELAN responses in SLI children with severe grammatical deficits. In this subgroup of children with SLI, syntactic violations did not elicit any ELAN response. Similar studies have not been conducted on children with ASD. While these preliminary findings are interesting, there are still only limited investigations of the mechanisms that underlie impairments in syntactic development in children with language disorders.

17.7.6 Neural Bases of Language Disorders

As noted earlier, in most individuals, regions that comprise the language network are asymmetric and larger in the left hemisphere. Functionally, the left hemisphere assumes a primary role in processing phonological, semantic, and grammatical aspects of language. Developmental studies have found that while the left hemisphere assumes language processing functions by the end of the first year, there is continuing developmental growth in the structure and asymmetry of language-related cortices into late adolescence (e.g., Sowell et al., 2004).

In children with SLI, both structural and functional differences have been found in studies using MRI. In general, these children have reduced volumes in the primary cortical language areas and reduced asymmetry in the frontal areas, and they are functionally less left lateralized (Tager-Flusberg et al., 2008). In ASD, similar atypical structural patterns have been found, although findings across different studies vary, depending on the methods used, and the age and characteristics of the participants. The majority of studies, which almost always include only boys with ASD, report reduced volumes of the pars triangularis in Broca's area and posterior language regions (e.g., McAlonan et al., 2005; but see also, Knaus et al., 2009). Interestingly, a recent study suggested that reduced volumes in these regions may be associated with later onset of language (McAlonan et al., 2008). Reduction in left hemisphere asymmetry of frontal language regions has also been found in several studies and is associated with greater impairment in language abilities (de Fossé et al., 2004). Almost all functional studies have been conducted with older children or adults. The most consistent findings are reduced left hemisphere asymmetry of language processing, especially in frontal areas, and reduced correlations in activation patterns across language regions (see Tager-Flusberg et al., 2008). One study found atypical activation to speech in toddlers with ASD (Redcay and Courchesne, 2008). In contrast to the control children, who activated the left hemisphere language network, toddlers with ASD primarily activated corresponding regions in the right hemisphere, suggesting that these atypical patterns begin early in development. It is not known, however, the extent to which these differences in functional organization of language in ASD are related to fundamental differences in neuroanatomy that are present at birth, to developing language skills, or to compensatory mechanisms. Nevertheless, the consistent pattern across a range of neuroimaging studies is that children with SLI or ASD are less likely than nondisordered children to depend on language areas in the left hemisphere for processing language.

17.8 CONCLUSIONS

The development of language is a remarkable accomplishment that depends on critical interactions between infants and their environment. Already at birth, attention and motivation bias newborns toward social stimuli, especially human language, and their brains seem tuned to selectively respond to linguistic stimuli. Over the first year of life, experience with language embedded in supportive social contexts leads to greater neural specialization and behavioral changes, and by their first birthday, most infants are already well on their way to acquiring the phonology, lexicon, and grammar of their target language. The course of development involves complex interactions between language-specific and other general cognitive, social, and physiological mechanisms, and the normal pathway depends on exquisite timing and synchrony across multiple domains. Future research will unravel further the neurocognitive systems that contribute to successful language acquisition, and as progress is made in discovering the genetic bases of language-related neurodevelopmental disorders, we will begin to understand how genes help to build a brain that is capable of learning how to speak and understand an abstract symbolic system in just a few short years (see Rubenstein and Rakic, 2013).

Acknowledgments

Support for preparation of this chapter was provided by grants from the National Institutes of Health (RO1 DC 10290) to H Tager-Flusberg and an Autism Speaks Weatherstone Predoctoral Fellowship to AM Seery.

References

Abrahams, B., Geschwind, D., 2008. Advances in autism genetics: On the threshold of a new neurobiology. Nature Reviews Genetics 9, 341–355.

Archangeli, D., Langendoen, D. (Eds.), 1997. Optimality Theory: An Overview. Blackwell, Malden, MA.

Baldwin, D., Meyer, M., 2007. How inherently social is language? In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Blackwell, Oxford, pp. 87–106.

Barlow, J., Geirut, J., 1999. Optimality theory in phonological acquisition. Journal of Speech, Language, and Hearing Research 42, 1482–1498.

Bartsch, K., Wellman, H.M., 1995. Children Talk About the Mind. Oxford University Press, Oxford.

Bates, E., Marchman, V., Thal, D., Fenson, L., Dale, P., Reznick, S., 1994. Developmental and stylistic variation in the composition of early vocabulary. Journal of Child Language 21, 85–123.

Benasich, A., Choudhury, N., Friedman, J., Realpe Bonilla, T., Chojnowlska, C., Gou, Z., 2006. Infants as a prelinguistic model for language learning impairments: Predicting from event-related potentials to behavior. Neuropsychologia 44, 396–411.

Bernal, S., Dehaene-Lambertz, G., Millotte, S., Christophe, A., 2010. Two-year-olds compute syntactic structure on-line. Developmental Science 13, 69–76.

Bloom, P., 2000. How Children Learn the Meanings of Words. MIT Press, Cambridge, MA.

Bosch, L., Sebastián-Gallés, N., 2001. Evidence of early language discrimination abilities in infants from bilingual environments. Infancy 2, 29–49.

Bowerman, M., 1978. Systematizing semantic knowledge: Changes over time in the child's organization of word meaning. Child Development 49, 977–987.

Brauer, J., Friederici, A.D., 2007. Functional neural networks of semantic and syntactic processes in the developing brain. Journal of Cognitive Neuroscience 19, 1609–1623.

Brown, R., 1973. A First Language. Harvard University Press, Cambridge, MA.

Bryant, J.B., 2009. Language in social contexts: Communicative competence in the preschool years. In: Gleason, J.B., Ratner, N.B. (Eds.), The Development of Language. Pearson, New York, pp. 192–226.

Burnham, D., Kitamura, C., Vollmer-Conna, U., 2002. What's new, pussycat? On talking to babies and animals. Science 296, 1435.

Butterfield, E., Siperstein, G., 1970. Influence of contingent auditory stimulation upon non-nutritional suckle. In: Bosma, J.F. (Ed.), Third Symposium on Oral Sensation and Perception: The Mouth of the Infant. Charles C. Thomas, Springfield, IL, pp. 313–334.

Byers-Heinlein, K., Burns, T., Werker, J., 2010. The roots of bilingualism in newborns. Psychological Science 21, 343–348.

Carpenter, M., Nagell, K., Tomasello, M., 1998. Social cognition, joint attention, and communicative competence from 9 to 15 months of age. Monographs of the Society for Research in Child Development 63 (4, Serial No. 255), pp. 1–176.

Carter, A., 1979. Prespeech meaning relations: An outline of one infant's sensorimotor morpheme development. In: Fletcher, P., Garman, M. (Eds.), Language Acquisition. Cambridge University Press, Cambridge, pp. 71–92.

Caselli, M., Casadio, P., Bates, E., 1999. A comparison of the transition from first words to grammar in English and Italian. Journal of Child Language 26, 69–111.

Cheour, M., Ceponiene, R., Lehtokoski, A., et al., 1998. Development of language-specific phoneme representations in the infant brain. Nature Neuroscience 1, 351–353.

Chomsky, N., 1995. The Minimalist Program. MIT Press, Cambridge, MA.

Curtiss, S., 1977. Genie: A Psycholinguistic Study of a Modern Day 'Wild' Child. Academic, New York.

de Fossé, L., Hodge, S.M., Makris, N., et al., 2004. Language-association cortex asymmetry in autism and specific language impairment. Annals of Neurology 56, 757–766.

de Villiers, J., Roeper, T., Vainikka, A., 1990. The acquisition of long distance rules. In: Frazier, L., de Villiers, J. (Eds.), Language Processing and Acquisition. Kluwer, Dordrecht.

DeCasper, A.J., Fifer, W.P., 1980. Of human bonding: Newborns prefer their mothers' voices. Science 208, 1174–1176.

DeCasper, A., Spence, M., 1986. Prenatal maternal speech influences newborns' perception of speech sounds. Infant Behavior and Development 9, 133–150.

Dehaene-Lambertz, G., Pena, M., 2001. Electrophysiological evidence for automatic phonetic processing in neonates. Neuroreport 12, 3155–3158.

Diehl, J.J., Bennetto, L., Young, E.C., 2006. Story recall and narrative coherence of high-functioning children with autism spectrum disorders. Journal of Abnormal Child Psychology 34, 87–102.

Diesendruck, G., 2007. Mechanisms of word learning. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Blackwell, Oxford, pp. 257–276.

Dubois, J., Hertz-Pannier, L., Cachia, A., Mangin, J.F., Le Bihan, D., Dehaene-Lambertz, G., 2009. Structural asymmetries in the infant language and sensori-motor networks. Cerebral Cortex 19, 414–423.

Eimas, P.D., Siqueland, E.R., Jusczyk, P., Vigorito, J., 1971. Speech perception in infants. Science 171, 303–306.

Ellis Weismer, S., Tomblin, J.B., Zhang, X., Buckwalter, P., Chynoweth, J.G., Jones, M., 2000. Nonword repetition performance in school-age children with and without language impairment. Journal of Speech, Language, and Hearing Research 43, 865–878.

Fernald, A., 1989. Intonation and communicative intent in mothers' speech to infants: Is the melody the message? Child Development 60, 1497–1510.

Floccia, C., Nazzi, T., Bertoncini, J., 2000. Unfamiliar voice discrimination for short stimuli in newborns. Developmental Science 3, 333–343.

Frank, M.C., Goodman, N.D., Tenenbaum, J., 2009. Using speakers' referential intentions to model early cross-situational word learning. Psychological Science 20, 579–585.

Friederici, A., 2006. The neural basis of language development and its impairment. Neuron 52, 941–952.

Friederici, A., 2009. Pathways to language: Fiber tracts in the human brain. Trends in Cognitive Science 13, 175–181.

Friederici, A.D., Wang, Y.H., Herrmann, C.S., Maess, B., Oertel, U., 2000. Localization of early syntactic processes in frontal and temporal cortical areas: A magnetoencephalographic study. Human Brain Mapping 11, 1–11.

Friedrich, M., Friederici, A.D., 2004. N400-like semantic incongruity effect in 19-month-olds: Processing known words in picture contexts. Journal of Cognitive Neuroscience 16, 1465–1477.

Friedrich, M., Friederici, A., 2005. Lexical priming and semantic integration reflected in the ERP of 14 month-olds. Neuroreport 16, 653–656.

Friedrich, M., Friederici, A., 2010. Maturing brain mechanisms and developing behavioral language skills. Brain and Language 114, 66–71.

Gernsbacher, M., Sauer, E., Geye, H., Schweigert, E., Goldsmith, H., 2008. Infant and toddler oral- and manual-motor skills predict later speech fluency in autism. Journal of Child Psychology and Psychiatry 49, 43–50.

Gervain, J., Macagno, F., Cogoi, S., Pena, M., Mehler, J., 2008. The neonate brain detects speech structure. Proceedings of the National Academy of Sciences of the United States of America 105, 14222–14227.

Granier-Deferre, C., Ribeiro, A., Jacquet, A.Y., Bassereau, S., 2010. Near-term fetuses process temporal features of speech. Developmental Science 13, 1–17.

Grossmann, T., Farroni, T., 2009. Decoding social signals in the infant brain: A look at eye gaze perception. In: de Haan, M., Gunnar, M. (Eds.), Handbook of Developmental Social Neuroscience. Guilford, New York, pp. 87–106.

Grunwell, P., 1981. The development of phonology: A descriptive profile. First Language 3, 161–191.

Guenther, F., 1995. Speech sound acquisition, coarticulation, and rate effects in a neural network model of speech production. Psychological Review 102, 594–621.

Hahne, A., Eckstein, K., Friederici, A.D., 2004. Brain signatures of syntactic and semantic processes during children's language development. Journal of Cognitive Neuroscience 16, 1302–1318.

Hale, C., Tager-Flusberg, H., 2005. Social communication in children with autism: The relationship between theory of mind in discourse development. Autism 9, 157–178.

Hall, G., Waxman, S. (Eds.), 2004. Weaving a Lexicon. MIT Press, Cambridge, MA.

Hickock, G., 2009. The functional neuroanatomy of language. Physics of Life Reviews 6, 121–143.

Hoff, E., 2006. How social contexts support and shape language development. Developmental Review 26, 55–88.

Hollich, G., Hirsh-Pasek, K., Golinkoff, R., 2000. Breaking the language barrier: An emergentist coalition model for the origins of word learning. Monographs of the Society for Research in Child Development 65 (3, Serial No. 262), pp. 1–123.

Houston-Price, C., Plunkett, K., Harris, P., 2005. 'Word learning wizardry' at I;6. Journal of Child Language 32, 175–189.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., Lyons, T., 1991. Early vocabulary growth: Relation to language input and gender. Developmental Psychology 27, 236–248.

Imada, T., Zhang, Y., Cheour, M., Taulu, S., Ahonen, A., Kuhl, P., 2006. Infant speech perception activates Broca's area: A developmental magnetoencephalography study. Neuroreport 17, 957–962.

Ingram, D., 1976. Phonological Disability in Children. Edward Arnold, London.

Iverson, J., 2010. Developing language in a developing body: The relationship between motor development and language development. Journal of Child Language 37, 229–261.

Iverson, J., Braddock, B., 2011. Gesture and motor skill in relation to language in children with language impairment. Journal of Speech, Language, and Hearing Research 54, 72–86.

Iverson, J., Thelen, E., 1999. Hand, mouth, and brain: The dynamic emergence of speech and gesture. Journal of Consciousness Studies 6, 19–40.

Iverson, J., Wozniak, R., 2007. Variation in vocal-motor development in infant siblings of children with autism. Journal of Autism and Developmental Disorders 37, 158–170.

Iverson, J., Hall, A., Nickel, L., Wozniak, R., 2007. The relationship between reduplicated babble onset and laterality biases in infant rhythmic arm movements. Brain and Language 101, 198–207.

Jusczyk, P.W., Pisoni, D.B., Mullennix, J., 1992. Some consequences of stimulus variability on speech processing by 2-month-old infants. Cognition 43, 253–291.

Jusczyk, P., Houston, D., Newsome, M., 1999. The beginnings of word segmentation in English-learning infants. Cognitive Psychology 39, 159–207.

Kaan, E., Swaab, T., 2003. Repair, revision, and complexity in syntactic analysis: An electrophysiological differentiation. Journal of Cognitive Neuroscience 15, 98–110.

Kent, R., 1999. Motor control: Neurophysiology and functional development. In: Caruso, A., Strand, E. (Eds.), Clinical Management of Speech Disorders in Children. Thieme, New York.

Kisilevsky, B., Hains, S., 2011. Onset and maturation of fetal heart rate response to the mother's voice over late gestation. Developmental Science 14, 214–223.

Kisilevsky, B., Hains, S., Lee, K., et al., 2003. Effects of experience on fetal voice recognition. Psychological Science 14, 220.

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

Klin, A., 1991. Young autistic children's listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. Journal of Autism and Developmental Disorders 21, 29–42.

Knaus, T.A., Silver, A.M., Dominick, K.C., et al., 2009. Age-related changes in the anatomy of language regions in autism spectrum disorder. Brain Imaging and Behavior 3, 51–63.

Kooijman, V., Hagoort, P., Cutler, A., 2005. Electrophysiological evidence for prelinguistic infants' word recognition in continuous speech. Cognitive Brain Research 24, 109–116.

Kuhl, P., 2004. Early language acquisition: Cracking the speech code. Nature Reviews Neuroscience 5, 831–843.

Kuhl, P., 2010. Brain mechanisms in early language acquisition. Neuron 67, 713–727.

Kuhl, P.K., Miller, J.D., 1982. Discrimination of auditory target dimensions in the presence or absence of variation in a second dimension by infants. Perception and Psychophysics 31, 279–292.

Kuhl, P.K., Coffey-Corina, S., Padden, D., Dawson, G., 2005. Links between social and linguistic processing of speech in preschool children with autism: Behavioral and electrophysiological measures. Developmental Science 8, F1–F12.

Kutas, M., Federmeier, K., 2011. Thirty years and counting: Finding meaning in the N400 component of the event-relation brain potential (ERP). Annual Review of Psychology 62, 621–647.

Landa, R., Holman, K., Garrett-Mayer, E., 2007. Social and communication development in toddlers with early and later diagnosis of autism spectrum disorders. Archives of General Psychiatry 64, 853–864.

Lenneberg, E., 1967. The Biological Foundations of Language. Wiley, New York.

Leonard, L., Eyer, J., Bedore, L., Grela, B., 1997. Three accounts of the grammatical morpheme difficulties in English-speaking children with specific language impairment. Journal of Speech, Language, and Hearing Research 40, 741–753.

Levy, Y., 1988. On the early learning of formal grammatical systems: Evidence from studies of the acquisition of gender and countability. Journal of Child Language 15, 179–187.

Lidz, J., Waxman, S., Freedman, J., 2003. What infants know about syntax but couldn't have learned. Cognition 89, B65–B73.

Lieberman, P., Crelin, E., Klatt, D., 1972. Phonetic ability and related anatomy of the newborn, adult human, neanderthal man and the chimpanzee. American Anthropologist 74, 287–307.

Locke, J., 1983. Phonological Acquisition and Change. Academic, New York.

Losh, M., Capps, L., 2003. Narrative ability in high-functioning children with autism or Asperger's syndrome. Journal of Autism and Developmental Disorders 33, 239–251.

Luyster, R.J., Kadlec, M.B., Carter, A., Tager-Flusberg, H., 2008. Language assessment and development in toddlers with autism spectrum disorders. Journal of Autism and Developmental Disorders 38, 1426–1438.

Markman, E., 1989. Categorization and Naming in Young Children. MIT Press, Cambridge, MA.

McAlonan, G.M., Cheung, V., Cheung, C., et al., 2005. Mapping the brain in autism. A voxel-based MRI study of volumetric differences and intercorrelations in autism. Brain 128, 268–276.

McAlonan, G.M., Suckling, J., Wong, N., et al., 2008. Distinct patterns of grey matter abnormality in high-functioning autism and Asperger's syndrome. Journal of Child Psychology and Psychiatry 49, 1287–1295.

McCleery, J., Tully, L., Slevc, L., Schreibman, L., 2006. Consonant production patterns of young severely language-delayed children with autism. Journal of Communication Disorders 39, 217–231.

McClelland, J., Patterson, K., 2002. Rules or connections in past-tense inflections: What does the evidence rule out? Trends in Cognitive Sciences 6, 465–472.

Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., Amiel-Tison, C., 1988. A precursor of language acquisition in young infants. Cognition 29, 143–178.

Menn, L., Stoel-Gammon, C., 2009. Phonological development: Learning sounds and sound patterns. In: Gleason, J.B., Ratner, N.B. (Eds.), The Development of Language. Pearson, New York, pp. 58–103.

Mills, D., Coffey-Corina, S., Neville, H., 1993. Language acquisition and cerebral specialization in 20-month-old infants. Journal of Cognitive Neuroscience 5, 317–334.

Mills, D., Coffey-Corina, S., Neville, H., 1997. Language comprehension and cerebral specialization from 13 to 20 months. Developmental Neuropsychology 13, 397–445.

Mills, D., Plunkett, K., Prat, C., Schafer, G., 2005. Watching the infant brain learn words: Effects of vocabulary size and experience. Cognitive Development 20, 19–31.

Minagawa-Kawai, Y., Mori, K., Naoi, N., Kojima, S., 2007. Neural attunement processes in infants during the acquisition of a language-specific phonemic contrast. Journal of Neuroscience 27, 315–321.

Mintz, T., Newport, E., Bever, T., 2002. The distributional structure of grammatical categories in speech to young children. Cognitive Science 26, 393–424.

Morgan, J., 1986. From simple input to complex grammar. MIT Press, Cambridge, MA.

Nadig, A., Ozonoff, S., Young, G., Rozga, A., Sigman, M., Rogers, S., 2007. A prospective study of response to name in infants at risk for autism. Archives of Pediatrics and Adolescent Medicine 161, 378–383.

Nagy, W., Scott, J., 2000. Vocabulary processes. In: In: Kamil, M., Mosenthal, P., Pearson, P., Barr, R. (Eds.), Handbook of Reading Research, vol. 3. Erlbaum, Mahwah, NJ, pp. 269–284.

Naigles, L., Swensen, L., 2007. Syntactic supports for word learning. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Blackwell, Oxford, pp. 212–231.

Nazzi, T., Bertoncini, J., Mehler, J., 1998. Language discrimination by newborns: Toward an understanding of the role of rhythm. Language 24, 756–766.

Nelson, K., 1981. Acquisition of words by first-language learners. Annals of the New York Academy of Sciences 379, 148–159.

Neville, H., Coffey, S., Holcomb, P., Tallal, P., 1993. The neurobiology of sensory and language processing in language-impaired children. Journal of Cognitive Neuroscience 5, 235–253.

Norbury, C., Tomblin, J.B., Bishop, D.V.M. (Eds.), 2008. Understanding Developmental Language Disorders: From Theory to Practice. Psychology Press, Hove.

O'Grady, W., Peters, A.M., Masterson, D., 1989. The transition from optional to required subjects. Journal of Child Language 16, 513–529.

Oller, K., 2000. The Emergence of Speech Capacity. Erlbaum, Mahwah, NJ.

Ozonoff, S., Iosif, A.-M., Baguio, F., et al., 2010. A prospective study of the emergence of early behavioral signs of autism. Journal of the American Academy of Child and Adolescent Psychiatry 49, 256–266.

Parish-Morris, J., Hennon, E., Hirsh-Pasek, K., Golinkoff, R., Tager-Flusberg, H., 2007. Children with autism illuminate the role of social intention in word learning. Child Development 78, 1265–1287.

Paul, R., Fuerst, Y., Ramsay, G., Chawarska, K., Klin, A., 2010. Out of the mouths of babes: Vocal production in infant siblings of children with ASD. Journal of Child Psychology and Psychiatry 52, 588–598.

Pinker, S., 1984. Language Learnability and Language Development. Harvard University Press, Cambridge, MA.

Pinker, S., 1999. Words and Rules. Basic Books, New York.

Preissler, M., Carey, S., 2005. The role of inferences about referential intent in word learning: Evidence from autism. Cognition 97, B13–B23.

Ratner, N., Bruner, J., 1978. Games, social exchange and the acquisition of language. Journal of Child Language 5, 391–401.

Redcay, E., Courchesne, E., 2008. Deviant functional magnetic resonance imaging patterns of brain activity to speech in 2–3-year-old children with autism spectrum disorder. Biological Psychiatry 64, 589–598.

Rice, M., 2007. Children with specific language impairment: Bridging the genetic and developmental perspectives. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Oxford, Blackwell, pp. 411–431.

Rice, M., Oetting, J., Maruis, J., Bode, J., Pae, S., 1994. Frequency of input effects on word comprehension of children with specific language impairment. Journal of Speech, Language, and Hearing Research 37, 106–122.

Rice, M., Wexler, K., Hershberger, S., 1998. Tense over time: The longitudinal course of tense acquisition in children with specific language impairment. Journal of Speech, Language, and Hearing Research 41, 1412–1431.

Rice, M., Cleave, P., Oetting, J., 2000. The use of syntactic cues in lexical acquisition by children with SLI. Journal of Speech, Language, and Hearing Research 43, 582–594.

Rivera-Gaxiola, M., Silva-Pereyra, J., Kuhl, P.K., 2005. Brain potentials to native and non-native speech contrasts in 7- and 11-month-old American infants. Developmental Science 8, 162–172.

Roberts, J., Rice, M., Tager-Flusberg, H., 2004. Tense marking in children with autism. Applied Psycholinguistics 25, 429–448.

Rowe, M.L., Goldin-Meadow, S., 2009. Early gesture selectively predicts later language learning. Developmental Science 12, 182–187.

Rubenstein, J.L.R., Rakic, P., 2013. Patterning and Cell Types Specification in the Developing CNS and PNS.

Saffran, J., Aslin, R., Newport, E., 1996. Statistical learning by 8 month-old infants. Science 274, 1926–1928.

Samuelson, S., Smith, L.B., 2000. Grounding development in cognitive processes. Child Development 71, 98–106.

Shatz, M., Gelman, R., 1973. The development of communication skills: Modifications in the speech of young children as a function of listener. Monographs of the Society for Research in Child Development 38 (5, Serial No. 152), pp. 1–37.

Sices, L., Taylor, H.G., Freebairn, L., Hansen, A., Lewis, B., 2007. The relationship between speech sound disorders and early literacy skills in preschool-aged children: Impact of co-morbid language impairment. Journal of Developmental and Behavioral Pediatrics 28, 1–10.

Siegal, M., Surian, L., 2007. Conversational understanding in young children. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Blackwell, Oxford, pp. 304–323.

Silva Pereyra, J.F., Klarman, L., Lin, L.J., Kuhl, P.K., 2005. Sentence processing in 30-month-old children: An event-related potential study. Neuroreport 16, 645–648.

Snow, C., 1977. The development of conversation between mothers and babies. Journal of Child Language 4, 1–22.

Sowell, E.R., Thompson, P.M., Leonard, C.M., Welcome, S.E., Kan, E., Toga, A.W., 2004. Longitudinal mapping of cortical thickness and brain growth in normal children. Journal of Neuroscience 24, 8223–8231.

Stoel-Gammon, C., 1998. The role of babbling and phonology in early linguistic development. In: Wetherby, A., Warren, S., Reichle, J. (Eds.), Transitions in Prelinguistic Communication: Preintentional to Intentional and Presymbolic to Symbolic. Brookes, Baltimore, MD, pp. 87–110.

Stoel-Gammon, C., Sosa, A., 2007. Phonological development. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Blackwell, Oxford, pp. 238–256.

Tager-Flusberg, H., 2004. Do autism and specific language impairment represent overlapping language disorders? In: Rice, M.L., Warren, S. (Eds.), Developmental Language Disorders: From Phenotypes to Etiologies. Lawrence Erlbaum Associates, Mahwah, NJ, pp. 31–52.

Tager-Flusberg, H., 2007. Atypical language development: Autism and other neurodevelopmental disorders. In: Hoff, E., Shatz, M. (Eds.), Blackwell Handbook of Language Development. Oxford, Blackwell, pp. 432–453.

Tager-Flusberg, H., Zukowski, A., 2009. Putting words together: Morphology and syntax in the preschool years. In: Gleason, J.B., Ratner, N.B. (Eds.), The Development of Language. Pearson, New York, pp. 139–191.

Tager-Flusberg, H., Calkins, S., Noin, I., Baumberger, T., Anderson, M., Chadwick-Denis, A., 1990. A longitudinal study of language acquisition in autistic and Down syndrome children. Journal of Autism and Developmental Disorders 20, 1–22.

Tager-Flusberg, H., Paul, R., Lord, C.E., 2005. Language and communication in autism. In: Volkmar, F., Paul, R., Klin, A., Cohen, D.J. (Eds.), 3rd edn. Handbook of Autism and Pervasive Developmental Disorder, vol. 1. Wiley, New York, pp. 335–364.

Tager-Flusberg, H., Lindgren, K., Mody, M., 2008. Structural and functional imaging research on language disorders: Specific language impairment and autism spectrum disorders. In: Wolf, L., Schreiber, H., Wasserstein, J. (Eds.), Adult Learning Disorders: Contemporary Issues. Psychology Press, New York, pp. 127–157.

Tager-Flusberg, H., Edelson, L., Luyster, R., 2011. Language and communication in autism spectrum disorders. In: Amaral, D., Dawson, G., Geschwind, D. (Eds.), Autism Spectrum Disorders. Oxford University Press, Oxford.

Thierry, G., Vihman, M., Roberts, M., 2003. Familiar words capture the attention of 11-month-olds in less than 250 ms. Neuroreport 14, 2307–2310.

Thiessen, E., Hill, E., Saffran, J., 2005. Infant-direct speech facilitates word segmentation. Infancy 7, 53–71.

Tomasello, M., 1999. The Cultural Origins of Human Cognition. Harvard University Press, Cambridge, MA.

Tomasello, M., 2002. Do young children have adult syntactic competence? Cognition 74, 209–253.

Tomasello, M., 2003. Constructing a Language. Harvard University Press, Cambridge, MA.

Tomblin, J.B., Zhang, X., 1999. Language patterns and etiology in children with specific language impairment. In: Tager-Flusberg, H. (Ed.), Neurodevelopmental Disorders. MIT Press, Cambridge, MA, pp. 361–382.

Ullman, M., 2001. A neurocognitive perspective on language: The declarative/procedural model. Nature Reviews Neuroscience 2, 717–726.

Valian, V., 1990. Null subjects: A problem for parameter-setting models of language acquisition. Cognition 35, 105–122.

Van der Leley, H., 2005. Domain-specific cognitive systems: Insights from grammatical-SLI. Trends in Cognitive Science 9, 53–59.

Vouloumanos, A., Werker, J.F., 2007. Listening to language at birth: Evidence for a bias for speech in neonates. Developmental Science 10, 159–164.

Waxman, S., 2003. Links between object categorization and naming: Origins and emergence in human infants. In: Rakison, D., Oakes, L. (Eds.), Early Category and Concept Development: Making Sense of the Blooming Buzzing Confusion. Oxford University Press, New York, pp. 213–241.

Weber, C., Hahne, A., Friedrich, M., Friederici, A., 2004. Discrimination of word stress in early infant perception: Electrophysiological evidence. Cognitive Brain Research 18 (2), 149–161.

Werker, J., McLeod, P., 1989. Infant preference for both male and female infant-directed talk: A developmental study of attentional and affective responsiveness. Canadian Journal of Psychology 43, 230–246.

Werker, J., Tees, R., 1984. Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. Infant Behavior and Development 7, 49–63.

Wetherby, A.M., Watt, N., Morgan, L., Shumway, S., 2007. Social communication profiles of children with autism spectrum disorders late in the second year of life. Journal of Autism and Developmental Disorders 3, 960–975.