Chapter 10
Support of Language and Communication Development as a Rationale for Early Maternal Vocal Contact with Preterm Infants

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Abstract *Introduction*. Preterm infants have an increased risk of language and communication disorders, and these disorders can occur even in the absence of brain lesions or major disabilities. There is a linear relationship between gestational age at birth and language development. This suggests that alterations in the anatomical and functional development of the premature brain contribute to the delayed language development of preterm infants.

Aim. The main aims of this chapter are to summarize the mechanisms and factors that affect language and communication delays in preterm infants and to present the rationale and discuss the potential use of early maternal vocal contact to promote language development.

Conclusions. Multiple medical and environmental factors contribute to language and communicative delays in preterm infants. Early and prolonged exposure of preterm infants to adult talk improves their language development. Competences in communication are acquired in social contexts. Physical closeness and early vocal contact between parents and preterm infants have the potentiality to support their language and communicative development. We suggest that clinicians consider the benefits of these interventions and that researchers further examine their effects.

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M. Filippa et al. (eds.), *Early Vocal Contact and Preterm Infant Brain Development*, DOI 10.1007/978-3-319-65077-7_10

Introduction

Despite improvements in perinatal care, preterm birth remains a significant risk factor for long-term neurodevelopmental problems. In particular, very preterm infants have a high risk of cerebral palsy and also of altered cognitive development, with several nationwide population-based follow-up studies reporting that such disorder occurs in nearly 40% of very or extremely preterm infants (Larroque et al., 2008, Marlow, Wolke, Bracewell, & Samara, 2005). Although survival of these infants without disability has improved in the past decade (Moore et al., 2012), a broader view of all the neurodevelopmental challenges these infants face is now available. Thus, many studies have highlighted the risk of psychiatric disorders in these infants, such as autism spectrum disorder, in which there are alterations of early communication skills, and learning disabilities. The seminal work of Limperopoulos et al. reported a high prevalence of a positive initial screening for autism spectrum disorders in survivors of extreme prematurity (Limperopoulos et al., 2008). Although the tools used to screen for these disorders have been discussed, other studies have confirmed the findings of Limperopoulos et al., especially in extremely preterm infants (Johnson et al., 2010).

The mechanism(s) responsible for psychiatric disorders in this population may include cognitive impairment and early traumatic experiences, events that impact children and parents. The risk for this condition appears to be specific to symptoms and disorders associated with inattention and social and communication problems, and manifests as a significantly higher prevalence of emotional disorders (Johnson & Wolke, 2013). In line with these neurodevelopmental morbidities, vulnerable preterm infants also have increased risk of disorders in speech and language development. A meta-analysis of large-scale follow-up studies reported these problems in more than one-quarter of such infants (Barre, Morgan, Doyle, & Anderson, 2011). Adequate early forms of communication and language competencies are essential for development of skills in interpersonal communication and social interaction. Language delay may also be associated with additional neurodevelopmental morbidities. Poor language skills negatively affect school success and long-term developmental progress and can also adversely affect the quality of social interactions (McCabe & Meller, 2004).

Although, there is a need to fully understand the nature of the specific language impairments in this population to improve detection of these disorders, it is also essential to implement early interventions for infants with language difficulties to improve their long-term outcomes.

Infants develop other forms of communication before language (see Gratier, Devouche, Chap. 4). Language can be divided into different categories and subdomains, and language development can be assessed by different tests (Barre et al., 2011). Infants begin early language development by listening to others, and then they begin to talk. Listening to voices is critical for the development of early forms of communication and speech. Here, we summarize the nature and factors associated

with communication and language delays in preterm infants and then discuss the potential of early maternal vocal contact as a strategy to promote language development in very preterm infants.

Communication Disorders and Language Delays in Preterm Infants

The aim of this first section is to identify and discuss the factors related to communication and language delays in preterm infants. During the process of language acquisition, early markers of general communication disorders can appear during the first months of life.

Ontogeny of Communication and Preterm Birth

Several components define social or communicative behaviors, such as vocalizations, facial expressions, gaze direction, and the capacity to coordinate these expressive behaviors during interactions with others. An infant learns these precursors of language based on rules of communication, such as reciprocal turn taking and shared timing and synchrony, through early social exchanges, and these are indices of co-regulation between adults and infants (Brazelton, Tronick, Adamson, Als, & Wise, 1975). Young infants develop a complex communication system within the first months of life. During development, they learn to coordinate their expressive behaviors between different modalities, such as vocalizations with mutual gazes at caregivers, and into specific patterns and thereby develop interactive and expressive competencies before the onset of speech (Yale, Messinger, Cobo-Lewis, & Delgado, 2003).

Within the first months of life, infants begin to organize patterns of shared social and interactive rhythms with sensitive parents or caregivers (Stern, Beebe, Jaffe, & Bennett, 1977). This parent-infant synchrony is central for the development of an infant's socio-emotional and cognitive capacities (Feldman & Eidelman, 2004).

Typical Synchrony in Communication

Synchrony between parents and infants, defined as the temporal coordination of microlevel social behaviors, follows from shared and repetitive rhythmic sequences (Bernieri & Rosenthal, 1991). Precursors of synchrony are evident in the first hours after birth and consist of gestures, postures, gazes, and vocalizations (Trevarthen, Chap. 1; Gratier, Devouche, Chap. 4). This suggests that humans are "wired" to engage in coordinated interactions, presumably because these interactions are essential for survival.

The different parameters of synchrony are useful in predicting infant development, because they shape the child's social-emotional and cognitive development. Synchrony correlates with better attachment behavior in 1-year-olds, with lower levels of behavioral problems in 2-year-olds, and with infant-directed and symbolic expression and several indices of self-regulation (Feldman, 2007).

As thoroughly described in Chap. 1, parents and infants gradually learn to achieve synchrony in their mutual exchanges as the infant develops. However, certain high-risk events, such as preterm birth, can disrupt the normal development of these interactions.

Lack of Synchrony due to Prematurity: An Early Marker of Communicative Delays

Preterm infants typically have different forms of communication than infants born at full term. Dyads with full-term infants show higher coherence than those with preterm infants at 3 and 5 months of age, and full-term infants more often led these interactions at both ages (Lester, Hoffman, & Brazelton, 1985). Parents often have difficulty reading the behaviors and emotional signals of premature infants (Eckerman, Oehler, Medvin, & Hannan, 1994), and these infants have limited ability to tolerate face-to-face interactions during a calm and awake state (Eckerman, Hsu, Molitor, Leung, & Goldstein, 1999). The preterm infant's biological dysregulation affects parental behavior, and parents are less coherent with infant displays during their interactions. Early contact experiences, such skin-to-skin contact (SSC), can modify these patterns into more cohesive styles. This leads mothers and fathers to be more sensitive and less intrusive and infants to exhibit a less negative affect (Feldman, Weller, Sirota, & Eidelman, 2003).

Prematurity has a negative impact on the bonding and attachment process between parents and infants for multiple reasons (Welch & Ludwig, Chap. 15). Thus, via shared vocalizations, gazes, and touch contacts, mothers of premature infants tend to have decreased coordinated social contact with their infants (Lester et al., 1985).

In addition to the different behaviors of mothers of preterm infants, preterm neonates are also less competent at coordinating their social behaviors during their limited moments of calm alertness. Moreover, premature infants have lower synchrony when interacting with their mothers. In fact, both tend to engage in short and frequent mutual gazes that break off soon after initiation (Feldman, 2007). The temporal organization of social interactions is less synchronous and less mutually adaptive in dyads with a preterm infant than those with a full-term infant (Feldman, 2006), and there is debate regarding the etiology of these behaviors.

It is possible that the differences in synchrony of full-term and preterm infants with their parents may explain the subsequent differences in language ability. In other words, when the rhythms of social interaction are disorganized and lack coherence, as with preterm infants, this may disrupt the early steps of learning language.

Language Delays in Preterm Infants and Causal Medical Factors

Preterm infants commonly develop speech and language impairments as they mature (Barre et al., 2011). These impairments include problems with receptive language processing and expressive language production and deficits in phonological memory. These language or phonetic difficulties also indicate general difficulties in cognitive function (Wolke, 2008). Compared to children who were full term, children who were preterm have deficits in vocabulary, semantics, verbal processing, and memory. Premature birth is also associated with delays in receptive and expressive language (Böhm, Katz-Salamon, Smedler, Lagercrantz, & Forssberg, 2002; Vohr et al., 2000). A systematic review showed that preterm infants have lower scores on simple and complex language function tests throughout childhood. The differences in complex language functions of full-term and preterm infants persist during childhood and even increase from 3 to 12 years of age (van Noort-van der Spek, Franken, & Weisglas-Kuperus, 2012). In particular, preterm infants have more deficits in vocabulary, semantics (van Lierde, Roeyers, Boerjan, & De Groote, 2009), verbal processing, and memory (Lee, Yeatman, Luna, & Feldman, 2011) as compared to their peers born at term. Several previous neurophysiological studies have pointed to the possible mechanisms or characterized the problems associated with the difficulties in language function experienced by preterm infants. Thus, problems in auditory discrimination seem to be associated with difficulties in naming objects in 4-year-old children born preterm who had birth weights less than 1500 g (Jansson-Verkasalo et al., 2003, 2004). This decreased auditory discrimination seems linked to difficulties in maintaining active auditory attention, although passive auditory attention seems to be relatively preserved in 5-year-old children who were preterm infants (Dupin, Laurent, Stauder, & Saliba, 2000). In agreement, children who were born preterm also have greater difficulties in vocal perception tasks that require sustained efforts up to the age of 2 years (Bosch, 2011). Another hypothesis is that these infants cannot discriminate phonemes because of deficiencies in specialization for their mother's language. In other words, these infants may have a reduced "perceptual narrowing" for phonemes that are ecologically meaningful: increased discrimination for phonemes from the mother's language and diminished discrimination for phonemes from a foreign language (Jansson-Verkasalo et al., 2010).

Poor language outcomes of preterm infants occur even in the absence of major disabilities, leading to questions regarding their etiology. These could result from the "nosocomial" auditory environment preterm infants that are exposed in the neonatal intensive care unit (NICU) or from early alterations in the neuronal circuits responsible for voice perception and motor language skills.

Insults to the developing brain, such as intraventricular hemorrhage or periventricular leukomalacia, disrupt neural network development and obviously contribute to language deficits. Neurosensory impairment in auditory processing is a well-known cause of speech delay in infants, highlighting the importance of audi-

tory inputs for normal language development. Researchers first assumed that poor language learning in preterm infants was primarily related to socioeconomic factors (Adams-Chapman et al., 2015). However, other research indicated that language difficulties in preterm infants were independent of socioeconomic status (Van Noort-Van der Spek et al., 2012), indicating that preterm birth by itself increases the risk of language deficits. Moreover, language deficits are greater in infants who are more premature. In particular, there is a clear linear relationship between gestational age at birth and subsequent language abilities, and this association persisted after statistical control for child and family factors (Foster-Cohen, Edgin, Champion, & Woodward, 2007). These researchers suggested that alterations in the anatomical and functional development of the premature brain contribute to the language difficulties of preterm infants. Medical factors affecting brain growth and development, such as white matter injuries, certainly have a role (Woodward, Clark, Bora, & Inder, 2012). However, different neonatal white matter abnormalities lead to different language disabilities (Reidy et al., 2013).

Broncho-pulmonary dysplasia (Singer et al., 2001) and severe jaundice with associated hearing disorders (Amin, Orlando, Monczynski, & Tillery, 2015) can disrupt language development. Data regarding the impact of perinatal inflammatory processes, as in chorioamnionitis, are conflicting. A recent meta-analysis (van Vliet, de Kieviet, Oosterlaan, & van Elburg, 2013) and a multicenter longitudinal study of 1194 extremely preterm infants (Pappas et al., 2014) found no relationship between chorioamnionitis and language delay after adjustment for confounding factors. Interestingly, certain therapies can modulate language outcomes in infants with chorioamnionitis. More specifically, the timing of caffeine therapy seems to alter outcome, in that infants given early caffeine therapy had better outcomes than those given later caffeine therapy and no caffeine therapy (Gupte et al., 2016).

Oral motor coordination is necessary for expressive language competencies and good feeding skills. Indeed, there is overlap of the neural pathways involved in eating and language. Previous research reported associations between feeding difficulties and language impairment (assessed using the 3rd edition of the Bayley Scales of Infant and Toddler Development [Bayley III]) in a cohort of 1477 extremely preterm infants (Adams-Chapman et al., 2013). This suggests that feeding difficulties during infancy could help to identify infants who will subsequently develop language difficulties during early childhood.

A recent review concluded that the etiology of language deficits in children who were preterm infants is multifactorial, and is related to “degree of prematurity, neonatal morbidities, illness severity, hearing status, gender, language environment in the neonatal intensive care unit and in the home, maternal education level, social and environmental status of the family, and access to early intervention” (Vohr, 2016). Thus, many factors contribute to the language deficits of extremely preterm infants, with and without hearing loss (Vohr, 2014). Although environmental factors are not the only one involved, the deprivation of biologically meaningful auditory stimuli in preterm infants seems especially important in leading to poor language development.

Hospitalization as a Cause of Distress and Speech Deprivation: Environmental Factors Leading to Language Delays

The environment of the NICU, which can include painful stimuli and high levels of light and noise, can cause distress in preterm infants. These factors may also adversely affect the development of a preterm infant via epigenetic mechanisms (see Montirosso & Provenzi, Chap. 16). Moreover, early experiences play a critical role in shaping the development of the brain and of behavior. There are several critical periods – windows of opportunity – during brain development in premature infants (Lagercrantz, 2016). During these periods, synaptogenesis alters neural connectivity patterns, according to an individual's experiences and responses to the environment (Knudsen, 2004). The brain of a preterm infant does not develop as in the womb, and there are subtle differences in cerebral growth and development relative to a full-term infant (Ment, Hirtz, & Hüppi, 2009). This is due to prematurity itself and to exposure to a different environment (Perlman, 2001).

Among the many environmental factors that can influence language development in hospitalized preterm infants, we focus on two specific components: auditory dys-stimulation in the NICUs (amount, duration, and type) and early maternal/paternal separation.

Auditory Dys-stimulation After Preterm Birth

It is still unknown whether a preterm infant is exposed to too much or too little auditory stimulation during hospitalization, and there are many additional unanswered questions. How much sound is best for promotion of infant language and communicative development? How long should these sounds last? What kinds of sounds are best, and who should deliver these sounds to hospitalized preterm infants? Do preterm infants in the NICU experience acoustical deprivation (Philbin, Chap. 6; Pineda et al., 2012)? Or are they specifically deprived from significant, caring, and contingent visual-tactile-acoustical stimuli?

The NICU has many loud and unpredictable sounds, and these can have detrimental effects on the physiological stability of preterm infants (Kuhn et al., 2012). Even moderate acoustic changes can disrupt the sleep of very preterm infants (Kuhn et al., 2013).

Several studies have evaluated the impact of noise on preterm newborns (Wachman & Lahav, 2011). Noise levels in NICUs are only rarely beneath the threshold set by the American Academy of Pediatrics (45 dBA) (Lasky & Williams, 2009). Moreover, NICUs also have greater levels of high-frequency sounds compared to the womb, and this can negatively impact the anatomical organization of auditory cortical circuits (Lahav & Skoe, 2014). More specifically, an auditory stimulus, such as alarm sound, negatively impacts other sensory functions in premature infants. These sounds may reduce the ability of premature infants to memorize tactile manual information and detect differences between shapes (Lejeune et al., 2016).

Thus, preterm infants in NICUs are simultaneously overexposed to certain sounds but underexposed to the maternal voice relative to the in utero experience. During hospitalization, the preterm infant's exposure to the mother's voice declines dramatically from the prenatal period to the postnatal period (Hofer, 2005). The deprivation of the mother's voice in the NICU during this important period of synaptogenesis and sensitive brain development can impact auditory maturation and potentially impact communicative and language skills (Fifer & Moon, 1994.). During hospitalization, preterm infants hear the talk of medical professionals, often during stressful or painful medical interventions. These preterm infants hear much less infant-directed speech (IDS) in relational-based contexts that focuses on sharing of emotions.

No studies have compared the effects of exposure to direct and indirect speech in the NICU. However, one study showed that exposure to maternal voice recordings with high-pitch modulation increased the rate of nonnutritive sucking in preterm infants (Butler, O'Sullivan, Shah, & Berthier, 2014). This suggests that emotional speaking, which is typical of IDS, can motivate infant responses.

Moreover, talking in a simulated face-to-face situation to very low-birth-weight preterm infants, as opposed to the mere presence of a social partner, can help infants achieve a quiet attentive state (Oehler, Eckerman, & Wilson, 1988) and lead to increased eye opening and more time in an attentive state (Eckerman et al., 1994). To summarize, previous studies that documented the negative impacts of unpredictable and loud noises reinforce the importance of developing environmental measures to lower the sound level in NICUs. On the other hand, preterm infants are sensitive to IDS, so caregivers should provide appropriate multisensory stimuli to these infants in a reciprocal affective co-regulation and active contact. Listening to the mother's voice and integration of vocal, verbal, and facial emotional information provide an optimal environment for emotional exchange with preterm infants (Brück, Kreifelts, & Wildgruber, 2011).

Early Mother-Infant Separation

Historical studies of infants deprived from their parents have documented the detrimental effect this has on their growth and development. Fortunately, there are now very few conditions in which mothers and infants are separated – even for a limited amount of time. However, this still occurs in many NICUs in cases of premature birth. The presence of parents and other family members in European NICUs has increased over the past 10 years, but several barriers remain, particularly in southern European countries (Greisen et al., 2009). Although the continuous presence of a primary caregiver with a preterm infant, from admission to discharge, appears to improve short-term outcome (Örtenstrand et al., 2010), uninterrupted parental presence (24/7) is still rarely implemented, and its long-term effects are not yet established. Prematurity often imposes long periods of separation of mothers and infants, and this early separation can lead to diverse physiological, emotional, and behavioral problems that can persist throughout life.

Exposure to elevated stressors early in life can increase subsequent reactivity to stress in mammals (Maestripieri & Mateo, 2009). In particular, infants with medical

problems are more susceptible to elevated stress reactions in response to poor parenting. However, during early stressful experiences, such as pain, the primary caregiver is often absent. The presence of a parent could reinforce an infant's resilience. In the intrauterine life, fetuses experience total closeness with their mothers, and this interaction provides a basis for parent-infant synchrony (Feldman, 2007). This co-regulation is both driven and evidenced by similarities in physiology, such as heart rate and respiration synchrony, regulation of hormones (e.g., oxytocin), and behavioral coordination of communicative patterns.

Unique Effects of the Voices of the Mother and Other People on Development of Communication and Language Skills in Infants

Human Voices, Speech Processing, and Language in Preterm Infants: Neuroscientific and Medical Perspectives

Listening to voices is crucial for language development, as shown by the deleterious effect of hearing loss on language learning. The human voice is the most important sound in our auditory environment because it is a uniquely human signal. The development of language skills is supported by different theories and occurs in several steps early in the infant's life, but these steps are not fully understood (Kuhl, 2004; Gervain & Mehler, 2010). The unique and important role of exposure to voices – particularly the mother's voice – is crucial (Mayberry, Lock, & Kazmi, 2002; May et al., 2011).

Speech Processing and Language Development

Neural and behavioral research studies have shown that exposure to language influences the neural circuitry of infants, even before they can speak their first words (Kuhl, 2010). Other studies showed that language acquisition involves specific neural networks, in which there is a neural commitment early in development. In other words, the basic elements of language, learned initially, are pivotal during critical period for language development (Kuhl, 2004). Neonates can discriminate the sounds of different prosodies and between their own and foreign languages shortly after birth (Moon, Lagercrantz, & Kuhl, 2013). At birth, the newborn's brain can perceive human speech and has the basic ability to process auditory signals (Telkemeyer et al., 2009). In adults, spoken language activates a bilateral frontotemporal network, including the superior temporal sulcus, with a left hemispheric dominance. After initial processing in the auditory cortex, vocal information is processed in dorsal and ventral pathways that are partially dissociated (Belin, Fecteau, & Bedard, 2004).

A brain of a full-term newborn responds to spoken language shortly after birth and uses an auditory language network that is similar to that of adults (Perani et al., 2011), although there are conflicting results regarding hemispheric predominance.

Some studies reported a right predominance, but others reported a left predominance already in full-term newborns (as in adults) following exposure to native language (Sato et al., 2012; Vannasing et al., 2016), infant-directed speech (Peña et al., 2003), and the mother's voice rather than an unfamiliar voice (Beauchemin et al., 2010). Taken together, all these studies argue for an essential biological basis for language acquisition early in the postnatal life. Other research also confirmed left hemisphere dominance in 2-month-old healthy newborns (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002). Moreover, the mother's voice, but not unfamiliar voices, triggers activity in other emotion-processing areas and in the left posterior temporal areas (Dehaene-Lambertz et al., 2010). This finding strongly suggests the mother's voice plays a special role in infants of this age in that it shapes early posterior language areas, especially in the left hemispheric language network.

Many studies of preterm infants indicate they have perceptual abilities and are attracted to the mother's voice (see Kuhn et al., Chap. 7). Cortical responses in the temporal and frontal areas, similar to those noted above, recorded using functional near-infrared spectroscopy (fNIRS) in preterm infants at ~30 weeks post-menstrual age, indicate these infants can discriminate two syllables (/ba/ vs. /ga/). Responses to novel male and female voices were also present but were more limited (Mahmoudzadeh et al., 2013). Using the same paradigm and high-density event-related potentials, these authors recently confirmed that early language processing networks are functional in infants born 10 weeks before term (Mahmoudzadeh, Wallois, Kongolo, Goudjil, & Dehaene-Lambertz, 2016). However, in this study of 19 very preterm infants, mismatch responses were more present and were precisely time-locked to event onset for changes in syllables, rather than changes in voices. The authors concluded that "human infants possess a strong genetic endowment to process speech features" and that the presence of these early networks before term constitutes a "functional intrinsic envelope" that can be "refined by exposure to a specific linguistic environment or impaired in the case of deprivation or inappropriate stimulation such as incubator noise." Despite the immaturity of the auditory pathways, a daily 3 h exposure to maternal sounds during the first postnatal month increased the width of the auditory cortex of 20 very preterm infants relative to controls, suggesting that the mother's voice can elicit auditory plasticity in the human auditory brain (Webb, Heller, Benson, & Lahav, 2015). Although there is still limited knowledge on how genetic and environmental factors interact during language development, researchers now acknowledge that both of these factors are important (Gervain, 2015).

Exposure to Human Voices, NICU Design, and Language Development

Consideration of the sensory part of language development indicates that exposure to human voices is crucial, as confirmed by an elegant prospective follow-up study of very preterm infants starting in the NICU. In particular, researchers recorded spontaneous vocalizations, the amount of adult word exposure, and the

extent of reciprocal conversational turns in 36 preterm infants (at 32 and 36 weeks of post-menstrual age) who had a mean gestational age of 27 weeks (range: 23–30) (Caskey, Stephens, Tucker, & Vohr, 2011). Greater exposure to adult talk correlated with more conversational turns, and this association was stronger for parental talk. At 7 and 18 months of age, language competencies and cognitive development (assessed using Bayley III) correlated positively with the adult word counts at 32 and 36 weeks, respectively. This supports the view that a preterm infant's exposure to adult words in the NICU before term equivalent age is associated with better cognitive, language, and communicative development during toddlerhood (Caskey, Stephens, Tucker, & Vohr, 2014). Studies evaluating the impact of NICU design (single family room, private room, or open-bay NICU) on the development of preterm infants support this view. In particular, private rooms in which there was very little parental presence and infant holding correlated with reduced hemispheric asymmetry at term in the language processing areas (temporal sulcus) and with worse language skills at 2 years of age (Pineda et al., 2014). This is presumably due to sensory deprivation and the lack of exposure to parents. However, other studies showed that single family rooms, rather than open-bay NICUs, were associated with greater maternal presence and involvement and with better neurobehavioral and medical outcomes in infants whose gestational ages were below 30 weeks (Lester et al., 2014). Whatever the NICU design, high maternal involvement with skin-to-skin contact correlated with improved 18-month neurodevelopmental outcome (higher language composite and better expressive and receptive communication scores on the Bayley III). This was especially the case for infants cared for in single family rooms that supported high maternal involvement (Lester et al., 2016).

To conclude, the preterm infant's brain, although immature, appears able to process speech. Exposure to adult talk, especially from the mother or father, has the potential to enhance their development of language and communication.

Psychosocial Arguments Supporting Early Vocal Contact to Improve Communication and Language in Preterm Infants

Early exposure to the mother's voice can improve a preterm infant's overall learning experience, including learning of language and cognitive development. Preterm infants are particularly sensitive to the sounds of language, such as adult talk and the sound of their mother's voice. They react to emotional voices, and the mother's voice can regulate the preterm infant's behavior by increasing its emotional and infant-directed features (Butler et al., 2014). The mother's live voice is emotional, and it regulates infant state changes and behavioral displays (Filippa, Gratier, Devouche, & Grandjean, 2017), and the emotional tone of maternal utterances can activate the neonate's brain.

Early forms of affective communication, which begin very early during extrauterine life and continue after birth, are fundamental for the reciprocal regulation of human beings and are important early forms of learning.

Table 10.1 tentatively summarizes the typical psychosocial conditions in the NICU and in an optimal environment, in which a preterm infant can learn communicative and linguistic skills, with particular attention to the fundamental role of the mother's voice. This table summarizes our view that the environments of many NICUs can detrimentally affect language development in preterm infants.

Table 10.1 Psychosocial characteristics of preterm infants in a typical NICU compared with an optimal environment for acquiring language skills

	Typical NICU	Optimal environment
Exposure to infant-directed speech	Hearing sounds that are not meaningful and limited exposure to the voices of the mother and family	Hearing-sensitive infant-directed speech (IDS) and songs since birth improves language acquisition, word segmentation, vocalization, and social contact
Indirect exposure to voices of adults and siblings	Indirect exposure is often associated with painful/stressful medical procedures. Indirect conversations may be helpful if they are not too loud	Infants are inadvertent observers of adult voices, indicating the presence of social partners. Nearby adult and sibling voices, not specifically directed to infants, are common, potentially aiding language learning and more complex behavior
Social context	A fragmented social context due to the presence of strangers (medical and nursing staff) and limited presence of the mother	Early mastery of communication, prelinguistic, and linguistic skills, with learning in a social context
Multisensory experience of voices	Sources of sounds are often not evident. Few opportunities to match sounds with their visual and tactile referents	Auditory experiences typically lead to orienting responses and turning toward the sound source. Social events provide sensory redundancy (audiovisual speech). Parents and other caretakers provide a social context that contains amodal redundancy of the tactile, auditory, and visual sensory systems
Meaningful auditory experience	Repeated and continuous exposure to sounds that are not meaningful and possibly detrimental	Parents act as mediators between infants and the sound environment and provide biologically relevant sounds
Reciprocity and early co-regulation	Early separation and limited exposure to parents	Reciprocal early regulation, adjustment behaviors, responses and reciprocal adaptation, and progressive construction of a microhabitat. Key elements of a natural social and communicative intimate environment are present

Conclusion

Children born prematurely may have difficulty learning language because of difficulties in establishing early social interactions with their parents. Early contact with a caregiver's live voice is essential for normal communicative and language development, especially during this sensitive period of brain growth. There are complex relationships between early vocal contact, especially the mother's voice, with contingent social interactions that involve infant-directed speech, and early communicative competencies. Preterm infants have a biologic need for timed sensory exposures to speech. Genetic and environmental factors affect an infant's social and communicative abilities, and their inherited cognitive and behavioral abilities are affected by the environment. Appropriate multimodal experiences with a parent may be the best intervention to promote language development in preterm infants. Models of interventions that are based on the biology of mother-infant early interactions may help determine the appropriate amount and timing of interventions. Early interventions in infants with language difficulties can be beneficial (Law, Garrett, & Nye, 2008; Girolametto, Wiigs, Smyth, Weitzman, & Pearce, 2001). Early vocal contact with the mother or father appears to be essential for normal language development. However, scientific data that support this specific hypothesis are needed. Several studies that will directly test this hypothesis are currently being planned or in progress. Early interventions that may help sustain parent-infant synchronization include methods that employ face-to-face vocal and affective contact delivered in close proximity, as during skin-to-skin contact.

Key Messages

- Vulnerable preterm infants have increased risk of disorders in communicative and language development, mainly due to medical and environmental factors.
- Auditory dys-stimulation and mother-infant separation can have detrimental effects on preterm infants' communicative and language development.
- Better cognitive, language, and communicative development of preterm infants are linked to exposure to human voices.
- Appropriate multimodal experiences with a parent, including methods that employ face-to-face vocal and affective contact delivered in close proximity, may be the best early intervention to promote language development in preterm infants.

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