Chapter 3
The Maternal Voice as a Special Signal for Infants

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Abstract Mothers throughout the world vocalize to infants in the course of caregiving. This chapter describes (1) mothers' speech and singing to infants, including differences arising from cultural practices and individual circumstances, and (2) the impact of maternal speech and singing on infants. Vocalizations to infants are more expressive than vocalizations to others, and they are often accompanied by gestures in other modalities. Although infants are sensitive to voices in general, they are particularly sensitive to the expressive style of infant-directed vocalizations and to the familiarity of the maternal voice. Infant-directed vocalizations, whether speech or singing, are effective in capturing infant attention, but infant-directed singing is more effective than infant-directed speech for regulating infant emotion or arousal. The maternal voice seems to function as a source of security and stimulation for infants, enhancing mother-infant bonds and promoting infants' social, emotional, and cognitive development.

Human Vocalizations

Human vocalizations are biologically and socially significant for listeners of all ages. In the newborn period, infants listen longer to speech than to artificial sounds that mimic the pitch contours and timing of speech (Vouloumanos & Werker, 2007). A few weeks later, they smile socially to voices before they begin smiling to faces (Wolff, 1963). The unique timbre or sound quality of a natural voice activates voice-sensitive regions in infant and adult brains (Belin, Zatorre, & Ahad, 2002;

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Blasi et al., 2011; Grossmann, Oberecker, Koch, & Friederici, 2010), with the activation being more intense for emotional than for neutral vocalizations (Grossmann et al., 2010).

Familiar voices have more potent effects than unfamiliar voices, regardless of the age of the listener. For example, newborns recognize their mother's voice and prefer it to the voice of a stranger (DeCasper & Fifer, 1980), presumably on the basis of prenatal exposure. A number of factors facilitate the recognition of familiar voices, including timbre or voice quality, pitch patterning or intonation (Bergeson & Trehub, 2007), and timing (rhythm and speaking rate) (Vongpaisal, Trehub, Schellenberg, van Lieshout, & Papsin, 2010). Although familiar voices are a source of comfort and pleasure for infants, they also enhance speech perception in infancy (Barker & Newman, 2004), as in the preschool years (Ryalls & Pisoni, 1997) and beyond (Nygaard, Sommers, & Pisoni, 1994).

Infant Listening Skills for Speech and Music

Maternal vocal communication, which features the most familiar voice, has special significance for infants. For preverbal infants in particular, melodic patterns (i.e., combinations of pitch and rhythm) in maternal speech and song are highly salient (Fernald, 1992; Trehub, 2016; Trehub & Trainor, 1998). Before considering the nature of maternal speech and song, it is important to consider the perceptual skills that make those sounds accessible and potentially meaningful to infant listeners.

Infants detect subtle pitch changes (i.e., a semitone or less) in a melody (Trainor & Trehub, 1992; Trehub, Schellenberg, & Kamenetsky, 1999), but they are especially sensitive to pitch relations. For example, they perceive the similarity of a melody and its transpositions—absolute pitch differences but pitch relations preserved (Chang & Trehub, 1977a; Trehub, Thorpe, & Morrongiello, 1987). They exhibit long-term memory for the pitch relations of instrumental melodies but not their absolute pitch level (Plantinga & Trainor, 2005). For vocal melodies, however, infants exhibit long-term memory for their pitch level (Volkova, Trehub, & Schellenberg, 2006) and pitch relations (Mehr, Song, & Spelke, 2016).

In some circumstances, infants notice a single changed note in a melody, whether it alters the contour, or pattern of directional pitch changes (Trehub, Thorpe, & Morrongiello, 1985), or preserves the contour (Trainor & Trehub, 1993). In general, however, they focus on the pitch contours of melodies—their overall shape—while ignoring small interval changes (Trehub et al., 1987). Infants' focus on melodic shape rather than pitch accuracy should allay the concerns of mothers who consider themselves poor or middling singers.

Most research on infants' perception of pitch patterns has been conducted with awake, alert, and cooperative infants who are 5 months of age or older. Surprisingly, there are striking parallels in sleeping newborns (1–3 days of age), which have been documented with electrophysiological methods. Such studies have revealed that the

neonatal brain is sensitive to changes in pitch direction—rising versus falling pitch (Carral et al., 2005)—and changes in interval size, large (seven semitones) versus small (two semitones) (Stefanics et al., 2009).

From 4 or 5 months of age, if not before, infants focus on the pitch contours of infant-directed speech (Fernald, 1989, 1992), which are often characterized as *speech melodies*. Note, however, that *speech melodies* have a loose correspondence to *musical melodies*. Pitch levels change much more rapidly in speech than in music, and intonation contours have larger and less precisely specified pitch excursions than melodic patterns in music (Zatorre & Baum, 2012). In any case, infants differentiate rising from falling pitch contours in speech (Frota, Butler, & Vigário, 2014; Soderstrom, Ko, & Nevzorova, 2011), but they do not link those differences to the speaker's intentions (e.g., questioning vs. stating). Infants also distinguish approving from disapproving/prohibition contours, which differ in the magnitude and smoothness of their pitch excursions (Fernald, 1993). Remarkably, the cries of French newborns are dominated by rising pitch, and those of German newborns are dominated by falling pitch, in line with the predominant pitch patterns of French and German speech (Mampe, Friederici, Christophe, & Wermke, 2009), a finding that implicates prenatal learning.

Infants are also sensitive to temporal aspects of music and speech. They detect changes in tempo (Pickens & Bahrick, 1995) and exhibit long-term memory for the tempo of familiar melodies (Trainor, Wu, & Tsang, 2004). They perceive temporal grouping or relative timing in music (Chang & Trehub, 1977b; Trehub & Thorpe, 1989) and the meter or pattern of strong and weak beats (Bergeson & Trehub, 2006; Hannon & Trehub, 2005). Temporal regularity is important for infant listeners, as evident by superior detection of pitch and timing changes in metrically regular music than in music with irregular timing (Trehub & Hannon, 2009). Even during sleep, newborn brains are sensitive to the beat of rhythmic music, as reflected in their responses to the omission of strong beats (Winkler, Háden, Ladinig, Sziller, & Honing, 2009).

Infants' perception of meter is influenced by movement experienced while listening to sound patterns. When 7-month-olds are bounced on every second beat to a drumming pattern with ambiguous meter (no accented beats), they perceive the pattern in duple meter; when bounced on every third beat, they perceive it in triple meter (Phillips-Silver & Trainor, 2005). Listening to rhythmic music also promotes rhythmic movement from about 5 months of age (Ilari, 2015; Zentner & Eerola, 2010), but such movement is not synchronized with the music. In fact, rhythmic movement does not become synchronized with music until about 4 years of age (McAuley, Jones, Holub, Johnston, & Miller, 2006). For younger children, greater synchronization is evident in social than in nonsocial contexts (Kirschner & Tomasello, 2009).

Synchronous movement to music has social as well as perceptual consequences. When 14-month-old infants are bounced to music and observe a synchronously or non-synchronously bouncing adult, they subsequently exhibit more prosocial behavior toward the adult who moved synchronously than to the other adult (Cirelli, Einarson,

& Trainor, 2014). Their prosocial behavior is selective rather than general, being directed to the synchronous bouncer and her friends but not to other adults (Cirelli, Wan, & Trainor, 2016). In the preschool period, synchronous singing and dancing promote prosocial behavior with peers (Kirschner & Tomasello, 2010).

Maternal Speech to Infants

As the most ubiquitous auditory signal for infants, it is not surprising that maternal vocal communication, speech in particular, has been the focus of extensive research. Mothers talk effusively to preverbal infants in a style that features higher pitch, more variable pitch and loudness, greater rhythmicity, slower rate, and warmer vocal tone relative to speech directed to adults (e.g., Fernald & Simon, 1984; Fernald et al., 1989; Narayan & McDermott, 2016). These various features contribute to the musical (Brandt, Gebrian, & Slevc, 2012; Fernald, 1989, 1992) and emotive (Trainor, Austin, & Desjardins, 2000) qualities of maternal speech. It is worth noting, however, that North American mothers' intonation patterns are more exaggerated than those produced by fathers and by mothers from other cultures (Fernald et al., 1989; Kitamura, Thanavisuth, Luksaneeyanawin, & Burnham, 2002). Moreover, individual differences within cultures are substantial (Narayan & McDermott, 2016).

Mothers intuitively adapt their speech to the age and needs of infants, which results in more comforting speech for 3-month-olds, more arousing speech for 6-month-olds, and more informing or directive speech for 9-month-olds (Kitamura & Burnham, 2003; Kitamura & Lam, 2009). The limited research on speech to newborns reveals predominantly soothing rather than stimulating vocal and nonvocal behaviors, reflecting caregivers' nurturing goals and concerns about overstimulation (Stern, Spieker, Barnett, & MacKain, 1983). In the case of congenitally deaf infants with cochlear implants (implants typically received at 12 months of age or later), mothers' use of approving and comforting speech is influenced by infant hearing experience (i.e., months of functional hearing) and age, and mothers' use of informing and directive speech is influenced by infant age or cognitive maturity (Kondaurova, Bergeson-Dana, Zu, & Kitamura, 2015).

In addition to the prosodic commonalities and variations that are evident within and across cultures (Fernald et al., 1989; Narayan & McDermott, 2016), there are unique or individually distinctive aspects of maternal speech. For example, each mother tends to use a limited set of unique interval sequences or *signature tunes* when speaking to her infant (Bergeson & Trehub, 2007), heightening the potency and memorability of her speech.

Mothers' vocal expressiveness or emotionality is also influenced by feedback from infants. When mothers interact face-to-face with infants, their speech is more emotive than it is in interactions at comparably close range but with infants obscured from view (Trehub, Plantinga, & Russo, 2016). The one-on-one, face-to-face context, which is typical of urban, middle-class interactions with infants from 2 or 3 months

to at least 6 months of age, allows mothers to monitor infants' engagement and fine-tune their communicative behavior to the needs of infants.

Face-to-face contexts provide infants with distinctive visual as well as vocal input. For example, mothers produce facial expressions that convey nurturance, wonder, or joy (Chong, Werker, Russell, & Carroll, 2003). These and other visual cues vary across languages, enabling adults to distinguish one language from another on the basis of visual cues (Soto-Faraco et al., 2007). Infants as young as 4 months of age also differentiate a familiar language—the one usually heard in their environment—from an unfamiliar language solely on the basis of visual cues (Weikum et al., 2007). Other modalities are involved in typical mother-infant interactions. For example, mothers often touch infants while interacting face-to-face, but touch is more pervasive in the absence of face-to-face contact, as when holding or carrying infants. Maternal touch varies with infant age, being more affectionate (e.g., stroking, patting) for younger infants and more stimulating (e.g., tickling) for older infants (Ferber, Feldman, & Makhoul, 2008; Jean, Stack, & Fogel, 2009).

Maternal challenges—emotional, social, or economic—affect qualitative and quantitative aspects of their speech. For example, depressed mothers interact less, vocalize less, and exhibit less affectionate vocal and nonvocal behavior with infants than do non-depressed mothers (Field, Diego, & Hernandez-Reif, 2006; Herrera, Reissland, & Shepherd, 2004). Similarly, mothers from economically disadvantaged backgrounds typically have fewer one-on-one interactions with their young children than do mothers from more advantaged backgrounds (Hart & Risley, 1995). As a result, infants from disadvantaged families often experience less infant-directed speech than their middle-class counterparts (Weisleder & Fernald, 2013).

Effects of Maternal Speech

Newborns and older infants are more attentive to speech in the maternal style than to conventional adult-directed speech (Cooper & Aslin, 1990; Fernald, 1985; Werker & McLeod, 1989). The happy-sounding quality of such speech seems to underlie its attention-getting properties in the first year (Kitamura & Burnham, 1998; Singh, Morgan, & Best, 2002), with such effects continuing into the second year as well (Segal & Newman, 2015). Maternal visual signals also have important consequences, but most research has focused on auditory aspects of stimulation. When 3- and 5-month-old infants are presented with side-by-side displays of silent talking faces (videos) in infant- or adult-directed style, they look preferentially at the infant-directed faces regardless of whether they hear infant-directed speech, adult-directed speech, or silence (Kim & Johnson, 2014). Audiovisual renditions of infant-directed speech influence infant affect as well as attention (Werker & McLeod, 1989).

The visual gestures that accompany talking not only distinguish one language from another (Soto-Faraco et al., 2007; Weikum et al., 2007); they also distinguish one person from another. After hearing infant-directed speech or singing from an unfamiliar person, adults successfully judge which of the two successively presented

silent videos corresponds to the person heard previously; 6- to 8-month-old infants look longer at the silent video of the previously heard person than at the video of a novel person (Trehub, Plantinga, Brcic, & Nowicki, 2013). These findings emphasize the unique, person-specific auditory and visual cues in speech and song.

In the early months of infancy, the mother's speech has wide-ranging social and emotional implications. Her sensitivity, which entails vocal and nonvocal behavior that is appropriate to the infant's age and needs, especially in the context of distress, is of particular importance (Leerkes et al., 2015). Nonvocal behavior such as holding and carrying, especially while moving (i.e., walking rather than sitting), is highly effective in calming crying infants (Esposito et al., 2013). Interestingly, maternal sensitivity in infancy has long-term emotional, social, and academic implications (Raby, Roisman, Fraley, & Simpson, 2015).

In later months, the quality and quantity of maternal speech have consequences for language development (Hoff, 2003; Hurtado, Marchman, & Fernald, 2007). By 18 months of age, notable differences in verbal processing and production are evident in children from economically disadvantaged backgrounds and those from more advantaged backgrounds (Fernald, Marchman, & Weisleder, 2013). The critical issue here is speech directed specifically to infants rather than speech that infants simply overhear. In fact, infants' exposure to one-on-one speech predicts language processing efficiency and vocabulary at 24 months of age (Weisleder & Fernald, 2013). Individual differences in attention also play an important role. For example, 12-month-olds' differential attention to speech and non-speech sounds is linked to expressive vocabulary at 24 months of age (Vouloumanos & Curtin, 2014).

Maternal Singing to Infants

Mothers across cultures sing to infants while providing care (Trehub & Gudmundsdottir, 2015; Trehub & Trainor, 1998). In societies where caregivers maintain almost constant physical contact with infants and value infant tranquility, lullabies are the songs of choice. In cultures that prioritize face-to-face contact and infant stimulation, play songs are more frequent, with lullabies reserved primarily for bedtime routines.

Analyses of caregivers' singing, which have focused largely on play songs, have revealed that mothers and fathers sing at a higher pitch level, slower tempo, and with warmer vocal tone when singing to infants than in other contexts (Trainor, Clark, Huntley, & Adams, 1997; Trehub, Unyk, & Trainor, 1993, Trehub et al., 1997). Infants' presence is necessary to elicit fully expressive performances, as indicated by parents' reduced expressiveness in infants' absence (Trehub et al., 1997). An infant audience in itself is insufficient; the infant must also be visible. For example, mothers sing less expressively when their infant is out of view—behind an opaque screen—rather than in view (Trehub et al., 2016), which indicates that visual feedback from infants maximizes maternal expressiveness. Bodily contact may also enhance maternal vocal expressiveness, but this issue has not been studied to date.

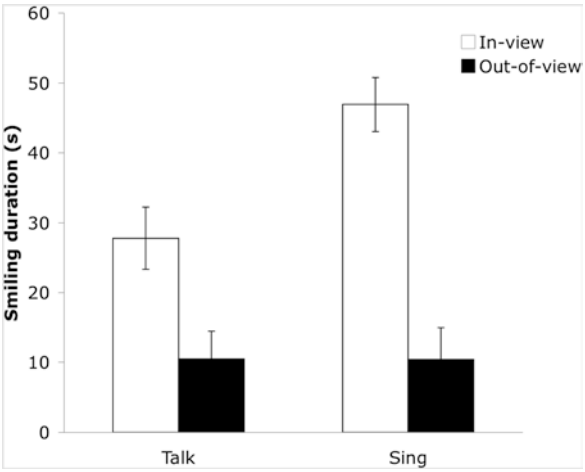

Fig. 3.1 Mean duration (in seconds) of maternal smiling while talking or singing to infants during a 60-second interaction when infants were in view or obscured from view (From Trehub et al. (2016))

Although mothers produce distinctive facial expressions when talking to infants (Chong et al., 2003), they smile considerably more when singing than when talking (Trehub et al., 2016). In fact, they smile almost constantly while singing in contrast to intermittent smiling while talking to infants (see Fig. 3.1). Many mothers also move while they sing—swaying from side to side or bobbing their head—generating multimodal musical performances that can be seen as well as heard. At times, mothers hold or move infants as they sing, adding yet another modality to the mix.

Effects of Maternal Singing

Newborns and older infants are more attentive to singing in the maternal style than to conventional informal singing by the same singer (Masataka, 1999; Trainor, 1996), a finding that parallels the listening preferences of newborns and older infants for infant- over adult-directed speech (Cooper & Aslin, 1990; Fernald, 1985). These listening preferences are generally attributed to the positive vocal tone or happy-sounding quality of infant-directed speech and singing (Corbeil, Trehub, & Peretz, 2013; Singh et al., 2002).

Although infant-directed speech and singing seem to be equally effective for *capturing* infant attention (Corbeil et al., 2013; Costa-Giomi, 2014), they differ in their efficacy for *sustaining* infant attention and regulating emotion. In one study that explored this issue, 7- to 10-month-old infants heard a continuously playing audio recording of a woman singing a children's song or speaking the lyrics in an infant- or adult-directed manner (Corbeil, Trehub, & Peretz, 2016). The question of interest was how long it would take before infants became visibly upset while listening to these materials in a relatively unengaging environment—a dimly lit room with no parent or other person in view. Surprisingly, infants listened to the song more than twice as long as to the speech before showing visible signs of discontent (a cry face) for 4 s (see Fig. 3.2). The presumption is that the regular beat

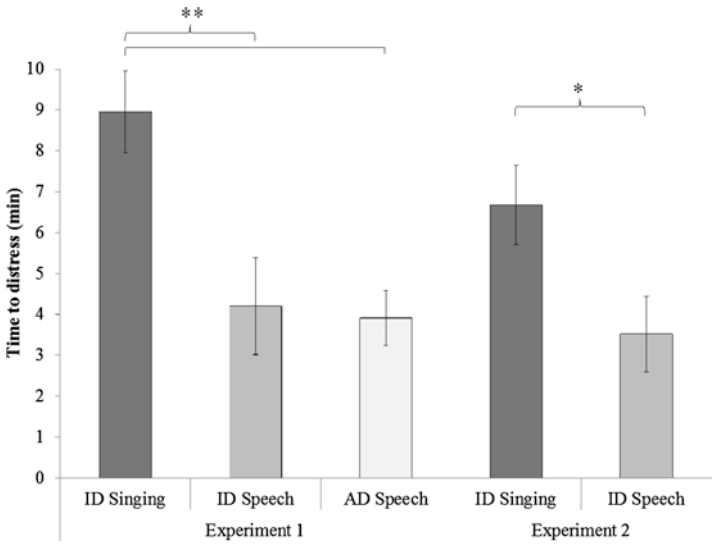

Fig. 3.2 Average time, in minutes, until infants became distressed while listening to speech, infant- or adult-directed, or singing. In Experiment 1, infants listened to a Turkish children's song or the spoken lyrics of that song. In Experiment 2, infants listened to infant-directed singing or speech in their native language (French) (From Corbeil et al. (2016))

of children's songs, which is typically lacking in speech (other than metrical poetry), prolongs infants' attention and relative contentment. If regularity in beat structure is important, then recited nursery rhymes should be more effective than conventional infant-directed speech in delaying infant distress. If the sustained pitches of singing are also relevant, then sung nursery rhymes should be even more effective than rhythmic recitations.

It is important to note that the stimuli in the aforementioned studies featured the voices of unfamiliar speakers and singers, either actors who simulated the maternal or non-maternal style or mothers of other infants who were recorded in previous natural interactions. The impact of such stimuli is likely to be enhanced by familiar voices and also by the opportunity to see as well as hear singers and speakers. Indeed, audiovisual recordings of maternal singing (own mother recorded in previous interactions with infants) are considerably more engaging to 6-month-old infants than comparable recordings of maternal speech (Nakata & Trehub, 2004). Moreover, the intensity of infants' engagement is evident not only from their extended visual fixations on the image of their singing mother but also in infants' physical stillness, another index of attention capture and engagement (Bacher & Robertson, 2001).

Even with unfamiliar singers and speakers, infants exhibit greater attentiveness to audiovisual versions of singing than to audiovisual versions of speech (Costa-Giomi, 2014). The temporal regularity of songs, the steady beat in particular, is likely to be implicated. There is suggestive evidence that infants use

the beat of infant-directed singing to listen in a predictive manner, as revealed by systematic eye movements to the singer's eyes in anticipation of the beat (Lense & Jones, 2016).

Audiovisual singing with familiar (maternal) and unfamiliar (maternal style) singers could be compared in future research. One would expect maternal singing to be advantageous because of many familiar elements aside from the mothers' familiar voice and face. As noted, mothers use a relatively small repertoire of songs that they sing repeatedly (Trehub et al., 1997), and they sing songs almost identically on different occasions (Bergeson & Trehub, 2002). Familiarity increases the appeal of music for adults (Szpunar, Schellenberg, & Pliner, 2004), and it is likely to do so for infants as well.

Live maternal singing has the potential for even greater infant engagement because of the possibility of performances attuned to infant feedback (Trehub et al., 2016). In fact, such singing, even in the absence of physical contact, modulates the arousal levels of contented 5- to 7-month-olds, as reflected in their salivary cortisol levels (Shenfield, Trehub, & Nakata, 2003). After maternal singing episodes, the arousal levels of infants converge relative to pretest levels. For example, infants with initially low arousal levels exhibit slight elevations, and those with initially higher levels exhibit slight reductions, reflecting a potential convergence on optimal arousal levels.

The aforementioned affect-regulatory consequences of audio versions of infant-directed singing (Corbeil et al., 2016) and the arousal-modulating effects of live maternal singing (Shenfield et al., 2003) were demonstrated with infants who were calm and contented, at least initially. To investigate the relative efficacy of multimodal maternal speech and singing (vocal, visual, and tactile stimulation) for reversing distress in 10-month-old infants, Ghazban (2013) used a version of the still-face procedure (Mesman, van IJzendoorn, & Bakermans-Kranenburg, 2009) that featured an initial play phase (60 s); a brief stress-induction phase (15 s) in which mothers were silent, immobile, and unresponsive while facing infants; and a final reunion phase (90 s) in which mothers interacted freely with infants except for their vocalizations being restricted to singing on some trials and to speech on others. The stress-induction manipulation was successful in the sense that infants' arousal levels rose substantially (i.e., elevated skin conductance levels), as did their negative facial and vocal expressions. In the reunion phase, maternal singing was considerably more successful than maternal speech in reducing covert (arousal) and overt (facial and vocal) signs of infant distress (see also Trehub, Ghazban, & Corbeil, 2015).

What factors could account for the efficacy of multimodal maternal singing in reversing infant distress? By singing songs that they usually sing at home, probably in a similar manner (Bergeson & Trehub, 2002), mothers provided highly familiar, rhythmically regular melodies and lyrics, supplemented at times with rhythmic movement. Presumably, the predictable style and content of maternal singing would be a source of comfort for infants who were experiencing stress. Although mothers spoke in an infant-directed manner, they did not have the advantage of scripted material, as when singing songs. Multimodal speech and singing both featured the

familiar maternal voice, but the singing episodes featured the same songs sung regularly at home, possibly performed in a similar manner (Bergeson & Trehub, 2002). In other words, the singing episodes provided greater overall familiarity than the speaking episodes, reassuring infants who were upset about their previously unresponsive mother. Moreover, the predictable timing of maternal singing (Nakata & Trehub, 2011) would support covert entrainment which, in turn, facilitates positive engagement with a social partner (Lense & Jones, 2016).

In short, the maternal voice, in song as in speech, is a powerful signal that helps forge and maintain emotional ties between mother and infant. As the maternal voice becomes more and more familiar over time, it becomes an increasingly potent source of security, comfort, and guidance for infants. To date, however, discussions of the mother (or primary caregiver) as an attachment figure and secure base for infants (e.g., Bowlby, 1998) have focused largely on maternal sensitivity in general, with little attention to maternal vocal sensitivity. The maternal voice, with or without accompanying facial expressions, touch, and movement (Corbeil et al., 2016; Ghazban, 2013), makes powerful contributions to infant emotional regulation and, ultimately, to emotional, social, and cognitive development. Undoubtedly, maternal singing affects the singer as well as the listener, but the consequences on mothers have not been explored to date. Nevertheless, the historical and cross-cultural record is consistent with the view that singing to infants, to others, and even to oneself has favorable consequences on the singer's well-being (Norton, 2016).

Implications for Prematurely Born Infants

Parenting is challenging at the best of times, but the birth of a premature infant presents a host of unexpected challenges. With high levels of uncertainty about the immediate and more distant future, it is not surprising that mothers of prematurely born infants experience greater levels of depression and anxiety than do mothers of full-term infants (Gray, Edwards, O'Callaghan, Cuskelly, & Gibbons, 2013; Miles, Holditch-Davis, Schwartz, & Scher, 2007). In too many cases, the result is enduring negative effects on mother-infant interaction (Forcada-Guex, Borghini, Pierrehumbert, Ansermet, & Muller-Nix, 2011) and infant emotional development (Voigt et al., 2013).

Maternal speech and singing are no panacea for the challenges of parenting a prematurely born infant, but they may provide a modicum of assistance in the NICU and beyond. If mothers understood that their tiny infant has functional hearing and the capacity to recognize their voice and to become familiar with their songs or recited nursery rhymes (Moon, Chap. 2, this volume), they might be motivated to begin nurturing the dyadic relationship by vocal means. In time, they could complement their vocalizations with other modalities of stimulation (e.g., touch, movement). If they understood that these interactions were likely to reduce the incidence of adverse medical events and promote calm, alert states in their fragile infants (Filippa, Devouche, Arioni, Imberty, & Gratier, 2013), and promote more positive outcomes thereafter,

they might be gratified by the opportunity to participate actively in their infant's care. Obviously, any such interventions in the NICU and at home must be tailored not only to the infant's health status and psychological needs but also to maternal psychological needs and patterns of distress (Holditch-Davis et al., 2015).

Key Messages

- Infants are sensitive to subtle differences in pitch and timing patterns and to the expressive nuances of maternal speech and singing.
- Mothers smile much more when they sing than when they speak to infants, which enhances the impact of maternal singing.
- Although infant-directed speech and singing have comparable efficacy in *capturing* infant attention, infant-directed singing is more effective in *sustaining* infant attention, delaying infant distress, and ameliorating infant distress.
- In view of the demonstrable benefits of maternal vocal behavior, it is important to find productive means of bringing some of those benefits to residents of the NICU.

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