# Building the bond:

# The social-emotional role of infant-directed speech & song

Victoria Hennessy[1] and T. Christina Zhao[1, 2]

[1] Institute for Learning & Brain Sciences, University of Washington

[2] Department of Speech & Hearing Sciences, University of Washington

## Author Note

Victoria Hennessy https://orcid.org/0009-0004-2739-1125

T. Christina Zhao https://orcid.org/0000-0003-1165-909X

Correspondence should be addressed to Victoria Hennessy, Institute for Learning & Brain Sciences, 1715 NE Columbia Rd, Seattle, WA 98195, United States, Box 357388. Email: vhenne@uw.edu. Phone: (206)-616-7351.

Keywords: *Emotional communication, attachment, infant-directed speech, infant-directed song, bonding, development*

**Acknowledgments**

The authors thank Dr. Zoe Cheng for comments on the initial draft. Research reported in this publication was supported by the National Institute On Deafness And Other Communication Disorders of the National Institutes of Health under Award Number R01DC020419 (PI: Zhao). The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health. The authors have no known conflict of interest to disclose.

**Abstract**

The bond between an infant and their primary caregiver plays a pivotal role in the infant's social, emotional, and cognitive development. Central to this bonding process is affective communication, a dynamic and multifaceted aspect of the caregiver-infant relationship. This review delves into the emotional dimensions of two primary modes of affective communication during infants' first year of life: infant-directed (ID) speech and infant-directed song. We directly compare literature using a side by side approach, focusing on how caregivers convey emotion, and how infants respond to such emotion, in ID speech and song. While existing research has recognized the affective nature of both phenomena, questions persist regarding the role ID speech and song play in real world interactions during the formation of the parent-infant relationship. To answer this, we dive deep into the social-emotional nuances of both channels, discuss the potential significance towards caregiver-infant bonding, and propose new paths to studying the parent-infant relationship through infant-directed vocalizations.

## Introduction

An integral part of human nature is the ability to create and maintain meaningful connections to one another. Developing the skills to do so begins in our very first relationship; the one between an infant and their primary caregiver (Bowlby, 1969/1982; Tronick, 1989). A strong caregiver-infant bond is vital for infants to form the framework for their future relationships (Bowlby, 1969/1982; Ainsworth et al., 1978; Tronick, 1989). Consequently, the quality of the bond is critical to an infant's social and emotional development (Gunnar et al., 1996; Waters et al., 2003; Groh et al., 2017).

Infants require caregiving that is attuned to their emotional cues and diverse needs, ensuring a sense of security to explore and learn within their environment (Ainsworth et al., 1978). However, the caregiving journey is no easy feat, and striving to promote positive developmental outcomes can be challenging for any primary caregiver (hereafter used interchangeably with "parent"). Cultivating stronger parent-infant relationships and facilitating healthy social development begins with understanding the multitude of ways primary caregivers interact and communicate emotion with their infants, such as infant-directed speech and song.

This review will first detail the process of bonding, attachment, and affective communication between parent and infant (Section 1), followed by an overview of infant-directed speech and song (Section 2). Subsequent sections will synthesize existing literature exploring the affective properties of infant-directed speech and song (Section 3), as well as infants' responses to either form (Section 4). To compare and contrast the two as mediums for emotional communication, a side by side approach will be used to (a) detail the expression of emotion in caregivers' ID speech versus song and (b) analyze infant responses to affect in ID speech versus song. Summarizing this knowledge may provide new insight into how ID speech or song work in the parent-infant relationship. It may also equip caregivers with strategies for fostering the bond with their infant, which could be particularly valuable for clinical

populations (Carvalho et al., 2019; Lam-Cassettari & Kohlhoff 2020). Overall, we aim to explore the role of emotion in ID speech and song toward early social bonding.

## 1. Understanding Bonding and Attachment

Exploration of the parent-infant relationship traces back to the seminal work of Bowlby and Ainsworth (Bowlby, 1969/1982; Ainsworth et al., 1978; Bowlby & Ainsworth, 2013). Attachment theory paved the way for the researchers who followed to study early bonding and attachment development as a highly reciprocal process, characterized by the exchange of signals and responses between both parent and infant (Kobak *et al*., 2016). Research over the next several decades expanded on Bowlby and Ainsworth's work to solidify the importance of caregiving that is both sensitive and reliable to infants' cues. Sensitive caregiving allows infants' to identify their primary caregiver as a safe base to rely on while they learn the basics of life; it is the catalyst for secure infant attachment, and sets the stage for healthy social development (Ainsworth *et al*., 1978; De Wolff & van Ijzendoorn, 1997; Raby *et al*., 2015). Multiple longitudinal studies have followed subjects from infancy to adulthood, providing substantial evidence that secure infant attachment forecasts stronger mental health, social-emotional awareness, and resilience to adversity (Waters, 2000; Schore, 2001; Ranson & Urichuk, 2008; Hamilton, 2000).

While bonding and attachment are interconnected, they are traditionally distinct concepts (Benoit, 2004; Kennell & Klaus, 1984; Ainsworth, 1989; Ettenberger *et al*., 2021). In this review, bonding is discussed as the critical process by which parents and infants establish a deep emotional connection over the infant's first year of life, leading to a lasting attachment from infant to parent that may predict the child's social, emotional, and cognitive outcomes (Bowlby, 1969; Feldman, 2007; 2012). At the core of the bonding process exists a cycle of natural reciprocity within parent-infant interactions, where shared affective communication is a critical cog in the formation of their relationship (Feldman, 2012; Papousek, 2007; Beebe, 2010).

Studying affective communication in naturalistic parent-infant interactions may reveal important implications about how our first relationships develop and evolve.

### *1.1 Affective Parent-Infant Communication*

Vocal communication, a primary means for parents to convey affective information to their infant, begins in the third trimester of pregnancy, as fetal hearing starts to develop and familiarize to the ambient auditory environment (Graven & Browne, 2008; Sullivan et al., 2011; Hepper & Shahiduallah, 1994; Decasper et al., 1994; Kisilevsky et al., 2009). At and following birth, neonates prefer and respond most consistently to the maternal voice, the predominant intrauterine sound (Decasper & Fifer, 1980; Lee et al., 2013). The range of communication modalities between parents and infants expands over time, and caregivers intuitively adapt their facial expressions, tone of voice, and other behaviors to augment their communicative intent in an appropriate manner for preverbal infants (Stern, 1974; Fernald, 1989; Chong et al., 2003; Carozza & Leong, 2021). In turn, the infant learns that their cues and signals can influence the response of their caregiver, activating the onset of *affective* or *emotional* communication, between one another (Tronick *et al*., 1989; Lavelli & Fogel, 2013). Parents and infants grow accustomed to each other's expressive behaviors and emotional states through affective communication (Tronick *et al*., 1989). Successfully reading and responding to each other's cues allows the pair to co-produce moments of mutual attunement in their daily interactions and behavior, through which they can establish a unique emotional connection, or bond (Jonsson, 2001; Kobak et al., 2016) (Figure 1). While channels of communication in infancy are complex and extensive (see Papoušek, 2007 for a comprehensive overview), this review will hone in on literature exploring the vocal and auditory exchange of emotional information in caregiver-infant interactions.

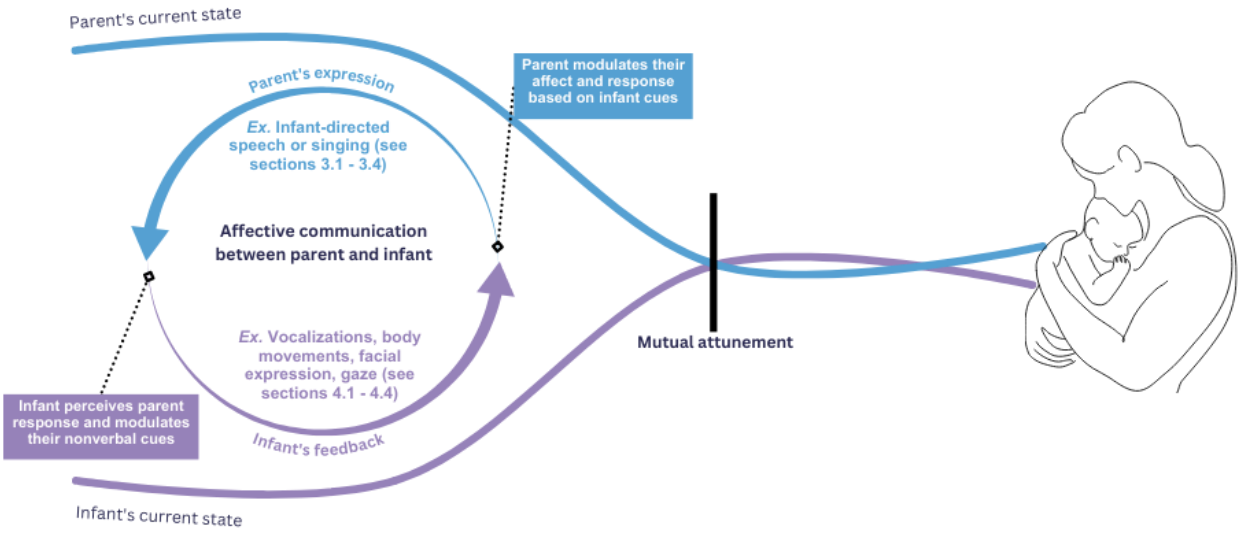


Figure 1. Early bonding as a continuous process facilitated by affective communication. Caregiver and infant bidirectionally read and respond to each other's emotional cues, leading to moments of attunement for both parties. Collective moments of interpersonal attunement are known to support the early caregiver-infant relationship.

**2. Infant-Directed Speech and Song**

Two universal ways we communicate verbally with infants are through infant-directed (ID) speech and song (Hilton *et al*., 2022; Yan *et al*., 2021). These multimodal forms of communication share a distinctive set of acoustic and prosodic features unique from the adult-directed (AD) dialogue. Major differences from AD vocalizations include increased pitch variability, slower tempo, and rhythmic regularity (Fernald et al., 1989; Bergeson & Trehub, 2002; Soderstrom, 2007; Spinelli *et al*., 2017). The distinctive acoustic properties of ID speech and song are found globally, and even in their nonnative language, humans are able to intuitively perceive whether vocalizations are intended for an infant or an adult (Hilton *et al*., 2022). Perhaps most importantly, infants across cultures show a clear preference for both infant-directed speech and song over adult-directed versions (Fernald & Kuhl, 1987; Frank MC *et al*., 2020).

Decades of research have established the fundamental role ID speech plays to enhance phonological, semantic, syntactic, and pragmatic learning in early language acquisition (for reviews, see Soderstrom, 2007, Cristia, 2013, or Golinkoff et al., 2015). Contrasted to AD speech, ID speech is characterized also by its acoustically exaggerated vowels, a trait widely regarded to aid speech perception and processing (Kuhl *et al*., 1997; but also see McMurray et al., 2013) in addition to the altered prosodic cues. Today, consistent exposure to ID speech has emerged as a critical ingredient for language development (Ferjan Ramirez et al., 2023). However, light has been recently shed on other potential functions of ID communication. Kalashnikova *et al* (2017) proposed that caregivers do not intuitively emphasize their vowels in ID speech solely to capture infants' attention for language acquisition, but also to regulate arousal and express emotion, emphasizing that the functions of ID speech extend well beyond language learning. Yet, research on the role of infant-directedness in the developing caregiver-infant relationship—particularly in relation to ID speech—is limited.

Conversely, ID singing has been explored empirically as a mechanism for social bonding, and subsequently identified as a communicative medium that can strengthen the parent-infant relationship (Milligan et al., 2003; Persico et al., 2017; Nguyen et al., 2023). The melodic nature and affective qualities of ID speech may foster emotional connections between caregivers and infants akin to the effects of ID singing (Papoušek et al., 1991; Fernald, 1989; Trainor *et al*., 2000). However, the bulk of ID speech and song literature focuses only on (1) identifying specific acoustic characteristics in infant-directed versus adult-directed stimuli and/or (2) infants behavioral or physiological response in the same ID versus AD domain. Relatively little work has been done to compare the efficacy of ID speech versus ID song, side by side, as interpersonal tools. Given the homogeneity of both forms, caregiver-infant interactions involving ID speech and/or song may serve as ideal windows for observing and learning about early emotional communication and bonding. In the following sections, literature implementing ID speech and song will be examined with a focus on the social-emotional component in each

channel rather than language development. We aim to identify knowledge gaps and propose future research directions about the parent-infant bond and early emotional communication.

### *2.1 Measuring Affect In Infant-Directed Speech & Song Paradigms*

When investigating the affective qualities and responses to human vocalizations, Francis and Oliver (2018) discuss two main dimensions: valence, which refers to the expression of a positive versus negative emotion, and arousal, which pertains to the intensity of emotion expressed physiologically or behaviorally. To determine valence in caregivers' infant-directed speech and singing, researchers have primarily relied on acoustic features, such as contours in pitch or more broadly, prosody. Prosody can be measured objectively through speech analysis, but vocal affect typically requires subjective evaluation (Schwarz et al., 2023). Generally, positive emotions are expressed with a higher pitch and amplitude, while negative emotions, such as sadness, are expressed through a more monotone pitch and carry lower energy (Banse & Scherer, 1996). Measures of affect in ID stimuli are not limited to acoustics. A number of groups have also explored *behaviors* that accompany ID speech and song, and contribute to their emotional nature (Chong *et al*., 2003; Shepard *et al*., 2012; Carozza & Leong., 2021; Brand et al., 2002; Longhi, 2009).

The level of arousal elicited by infant-directed speech or singing is studied through infants' behavioral and physiological responses. Typical measures for infant arousal include heart rate, neural activity, skin conductivity, behavior coding, and cortisol levels (Santesso et al., 2007; Cirelli et al., 2020; Nakata & Trehub, 2004; Shenfield et al., 2003). One or more of these physiological metrics can be used in combination with coded behavioral observation(s), such as gaze, facial expression, or body movements. Examining the emotional expression in a parent's speech or song (the output) alongside the infant's responses to these stimuli (the input) can provide a glimpse into how ID speech and song facilitate affective communication in parent-infant interactions.

## 3. Expression of Emotion in Infant-Directed Speech & Song

| ID Speech | ID Song |
|---|---|
| Contains more salient acoustic emotional cues (e.g. higher pitch, prosodic contours), and specifically those expressing positive affect, than AD speech (Trainor et al., 2000; Schwarz et al., 2023). | More emotionally engaging when an infant is physically present, and conveys positive affect in either an upbeat or soothing style (Trehub et al., 1997, Rock et al., 1999). |
| Co-occurs with other emotional cues, including distinct facial expressions, affectionate touch, and infant-directed motions unique from those in AD speech (Chong et al., 2003; Abu-Zhaya et al., 2017). | Other dimensions of emotion, such as beat-synchronous body bouncing and affectionate touch, appear in ID song but not AD song (Longhi, 2009). |
| Tempo is dynamic, with more distinct prosodic cues, than AD speech (Fernald, 1989; Schwarz et al., 2023). | Tempo is more rhythmic and predictable than AD song, as well as modulated by whether the intention is to engage or soothe infant (Nakata & Trehub, 2011; Cirelli et al., 2020). |

Table 1. Qualitative comparison of emotional expression in ID Speech vs. ID Song in the literature. Note that nearly all existing studies compared ID and AD vocalizations in a single domain (speech *or* song) and the literature lacks studies that compare speech to singing directly, particularly in regard to affective content.

### *3.1 Acoustic Evidence of Emotion in ID Speech*

Emotion, particularly positive affect, is evident in the acoustics of infant-directed speech (Benders, 2013). Parents and caregivers increase prosodic cues and modifications (i.e. changing their pitch, volume, or syllabic stress) in speech directed to infants compared to speech directed to adults, creating fluctuations in auditory output that help infants link meanings to sounds (Papoušek et al., 1991; Fernald, 1989). A study by Trainor and colleagues (2000) was one of the first to hone in on the acoustics of specific emotions (love, comfort, surprise, and fear) by using recordings of mothers' ID speech and AD speech when given hypothetical emotional scenarios. Most prominently, they found that ID speech is more emotionally salient than AD speech, but the prosodic contours are surprisingly similar across categories of affect in ID vs AD versions, suggesting that both the cause—and effect—of ID speech is driven by the

expression of emotion. Using a more naturalistic design, Schwarz et al. (2023) looked at affect in mothers and fathers speech to 3- to 12-month-old infants during a free play session versus their speech while talking with an adult. Affect valence, as determined by intersubjective ratings, differed in parents' ID speech to 12-month-olds compared to their AD speech; on average, ID speech received higher scores of positive affect than AD speech (Schwarz et al., 2023). Thus, these findings align with Trainor et al.'s despite the stark difference in study design (i.e., using scripted ID speech intended to evoke a specific emotion versus ID speech produced naturally during parent-infant interactions). Across the board, ID speech is more abundant in vocal affect than AD speech, likely to help preverbal infants' understand and connect with their parents before language onset (Trainor et al., 2000; Benders, 2013; Schwarz et al., 2023). In this regard, several teams have tested whether ID speech or AD speech is more effective in depicting emotional intent. Adult listeners are able to identify speaker intent, relying only tone of voice (i.e. prohibition, approval, and comfort), with much greater accuracy in ID speech than in AD speech, demonstrating that the acoustic qualities in ID speech can effectively convey emotional information, even without linguistic knowledge (Fernald, 1989; Bryant & Barrett; 2007).

### *3.2 Other Dimensions of Emotion in ID Speech*

Beyond acoustics, the emotional components of ID speech are presented in a multimodal format that include unique alterations to countenance, tactile cues, and body movements. A well recognized phenomenon is the link between expanded intonation contours of ID speech (i.e., elevated pitch) and facial expressions of positive affect in mother-infant interactions (Benders, 2013). Smiling, raised eyebrows, and wide eyes are exhibited synonymously with ID speech and believed to strengthen caregivers' affective intent (Chong *et al*., 2003; Shepard *et al*., 2012). Parents also fuse their linguistic and facial cues with tactile ones. Affectionate touch--soft stroking, holding, or pressure--often accompany ID speech,

providing tactile stimulation to support infants' emotion regulation and promote social connection (Abu-Zhaya *et al*., 2017; Carozza & Leong, 2021; Croy *et al*., 2022). Finally, the layered experience of ID speech is rounded out by the use of infant-specific gestures that parents use while speaking to their infants; Brand et al. (2002) coined it "motionese". There is indeed a select set of gestures, coupled with ID speech but not AD speech, that appear to enhance the meanings behind actions and magnify emotional expressions intended for preverbal infants (Brand et al., 2007; Koterba, 2009). Collectively, the acoustic and behavioral properties of ID speech make it an ideal medium for affective communication during early bonding between parent and infant.

### *3.3 Acoustic Evidence of Emotion in ID Song*

When singing to infants, caregivers use a more emotionally engaging and "loving" tone of voice than they do in the same song performed without an infant present (Trainor, 1996; Trehub, Unyk, *et al*., 1997). Observed in playsongs and lullabies, ID singing is distinguished by a slower, hierarchical tempo, reduced pitch variability, and more pronounced pauses as opposed to adult-directed singing (Trainor et al., 1997; Longhi, 2009; Hilton et al., 2022). Acoustics of an infant-directed song can vary depending on whether the caregiver wants to soothe or stimulate the infant, as well as infant response (Rock *et al*., 1999; Carvalho et al., 2019; Longhi et al., 2009). The style of song can help caregivers diffuse an emotionally charged situation, such as calming a fussy infant, but can also maintain infants' attention and arousal during moments of parent-infant play and bonding (Trainor *et al*., 1997; Corbeil *et al*., 2013; Cirelli et al., 2020). Furthermore, the temporal structure of ID songs is different from its AD counterpart, and thought to be calibrated to infants' sensory abilities (Nakata & Trehub, 2011). In infant-directed versus adult-directed renditions of *Twinkle, Twinkle, Little Star* sung by mothers and non-mothers, infant-directed performances had less expressive variation in timing and a greater dynamic range (Nakata & Trehub, 2011). Mothers also emphasize the hierarchical

structure as they sing to their infants, exaggerating the upbeats to cue to the infant that the downbeat is coming next (Longhi, 2009). This regularity may help an older infant learn to anticipate and match the beat of the song (i.e. clapping along at the right moments) which creates opportunity to coordinate and connect with their caregiver (Cirelli, 2018; Markova et al., 2020).

### *3.4 Other Dimensions of Emotion in ID Song*

Infant-directed singing, much like infant-directed speech, is a multidimensional experience for caregivers and infants. Body bouncing, head nodding, and affectionate touch (i.e. caressing) are just a few examples of the physical behaviors parents exhibit while singing to their infants (Longhi, 2009). Moreover, caregivers match their movements to the beat of the song, creating an interactive experience through which the dyad can coordinate to exchange emotional information (Longhi, 2009). Maternal smiling and rhythmic movements are characteristic of upbeat ID songs (i.e. playsongs), which may contribute to associations found between synchronized motion and prosociality in infants (Cirelli et al., 2014; Cirelli et al., 2020). This corroborates with findings of increased maternal smiling and general emotiveness during infant-directed singing, but only when their infant is in view (Milligan et al., 2003; Trehub et al., 2016). When paired with modified acoustics, the nonverbal emotional expression in ID singing serves to enhance parental intentions and positive affect, thereby promoting stronger affective communication and social connection.

## 4. Infants' Responses to ID Speech & Song

| ID Speech | ID Song |
|---|---|
| Infants exhibit a preference for ID speech that expresses positive affect; they prefer happy-sounding speech in general (Singh et al, 2002; Corbeil et al., 2013). | Infants' display more positive behaviors to ID song than AD song (Masataka, 1999; Trainor, 1996; de l'Etoile, 2006). |

| | |
|---|---|
| Infants are sensitive to positive and negative affect in ID speech stimuli (Fernald, 1993). | ID singing is most effective at soothing a distressed infant, compared to ID/AD speech and AD singing (Corbeil et al., 2016). |
| Infants respond to emotion at the neural level; fear evokes the strongest response in the frontal cortex (Santesso et al., 2007; Nozomi et al., 2012). | ID singing helps infants direct their gaze to their caregiver and learn to engage in social visual behavior (Lense et al., 2022). |
| Prosody in ID speech impacts infant heart rate and may directly influence infants' autonomic state (Kolacz et al., 2022). | Infants' arousal levels are modulated by the emotional style of ID song (Cirelli et al., 2020). |

Table 2. Qualitative comparison of infants' behavioral and physiological responses to ID Speech and ID Song based on existing literature.

*4.1 Infants' Behavioral Responses to ID Speech*

Evidently, infant-directed speech is infused with emotional information that helps infants' discriminate affective intent from the speaker (Fernald, 1993). Studies looking at affect as a primary construct of ID speech are few and far between; however, it's generally acknowledged that infants are sensitive to and prefer speech that is more emotional. Specifically, happy-sounding speech (Singh et al., 2002; Corbeil et al., 2013). From the start, newborns open their eyes more frequently to the language of their caregiver when the speech is expressed in a happy voice versus a sad or neutral tone (Mastropieri & Turkewitz, 1999). Even when hearing ID speech in an unfamiliar language, Fernald (1993) found that 5-month-olds smile more frequently to positive vocal affect (i.e. approval) and frown/tense their brow to negative vocal affect (i.e. prohibition). Notably, these infants did not show these differential responses to the stimuli when it was adult-directed. The behavior appears to persist throughout development; Kao et al. (2022) demonstrated three- to twelve-month-old infants generally direct more attention to happy ID speech over neutral or angry speech. This aligns with preceding works: infants prefer speech that is expressed with positive emotion, which supports why ID speech is "exceptionally emotional" compared to AD speech (Trainor et al., 2000).

### *4.2 Infants' Physiological Responses to ID Speech*

Infants also respond to emotion in ID speech at a psychophysiological level. Santesso et al. (2007) showed that EEG power in the frontal region of 9-month-olds is linearly correlated to the intensity of emotions in infant-directed speech stimuli. ID speech stimuli expressing fear elicited the highest frontal power compared to surprise and comfort (Santesso et al., 2007). This effect is reflected in areas of auditory processing; 4 to 13-month-old infants display greater increases in cerebral blood flow to recordings of positive ID speech across the temporal cortex compared to the AD versions (Nozomi et al., 2012). Greater activation to ID speech was also observed in the frontal area of the 7- to 9-month-olds, but only when the speech stimuli was generated by the infants' own mother (Nozomi et al., 2012). Thus, not only are infants sensitive to emotional content of ID speech, but are most attentive when it's the speech produced by their primary caregiver (Grossman et al., 2005; Santesso et al., 2007; Nozomi et al., 2012). In the same study by Santesso et al., it was also discovered that infants display a significant deceleration of heart rate in response to affective ID speech compared to a neutral baseline; these results support the influence of emotions on autonomic activity, even in preverbal infants (Ekman et al., 1983). Indeed, ID speech helps infants' regulate their emotions through biobehavioral effects. Kolacz et al. (2022) found that prosodic features in maternal ID speech are linked to infants' ability to calm themselves after a stressful event. Increased vocal prosody decreased infants' heart rates, suggesting that prosodic patterns in a mother's speech to her infant may directly modulate the infant's autonomic state (Kolacz et al., 2022).

### *4.3 Infants' Behavioral Responses to ID Song*

Consistent with infants' preference for affective vocalizations, a substantial body of evidence indicates that infants prefer ID singing over AD singing. Both neonates and 4- to 7-month-old infants listen more closely to singing when it's infant-directed than when it's adult-directed (Masataka, 1999; Trainor, 1996). Infants' between 6 and 9 months exhibit

heightened focus on their caregivers during live infant-directed singing, in which their gaze is directed toward the mother's face throughout the duration of her song (de l'Etoile, 2006). This attentiveness is considered representative of the infant's level of interest and willingness to interact with their mother. The same group of infants also displayed a series of positive physical behaviors in response to the ID singing, including touching, clapping, and reaching (de l'Etoile, 2006). More recently, Lense *et al*. (2022) showed that ID singing can entrain the visual behavior in infants' as young as 2 months; infants' gaze to their caregivers' eyes is not equal across the entirety of songs, but synced with the beats. From Lense's findings, it is evident that ID singing not only acts as a transfer of affective information within the dyad, but also teaches infants' important social engagement skills. Adding to the benefits, ID singing is highly effective in delaying infant distress. Corbeil et al. (2016) tested 7- to 10-month-old infants' ability to remain content under both ID vs AD and speech vs singing conditions; infants were able to maintain composure (i.e. not starting to fuss) for the longest period of time when presented with a recording of ID singing. Cumulatively, the findings suggest that infant-directed singing effectively captures and holds infants' attention, creating moments of opportunity for caregiver-infant bonding.

### *4.4 Infants' Physiological Responses to ID Song*

Even in their earliest stages, infants exhibit physiological responses to emotion in infant-directed singing (Nagy et al., 2022). In 5 to 7 month old infants, variance in cortisol levels was significantly reduced from the baseline period when mothers' began to sing (Shenfield et al., 2003). Older infants' (8 to 11 months) arousal levels are influenced by the style of song sung by their mother, according to Cirelli et al. (2020). In alternating trials, Cirelli's infants' heard two renditions—soothing or playful—of *Twinkle, Twinkle Little Star*. Using salivary cortisol to measure arousal, Cirelli's group found that infant's arousal levels decreased with the soothing version, but maintained relatively stable levels during the playful rendition (but were more

attentive to their mothers). These results are somewhat contradicted by earlier studies, in which infants' displayed a greater decrease in arousal listening to playsongs than when they listened to lullabies (Ghazban et al., 2013; Trehub et al., 2015). However, it's important to note that the paradigms between the earlier studies and Cirelli et al.'s differ; the latter two tested infants' arousal levels after inducing stress through the Still-Face paradigm, while Cirelli's procedure allowed caregivers and infant's to maintain face-to-face contact from start to finish (for background on the Still-Face paradigm, see Tronick et al., 1978 or Mesman et al., 2009). Importantly, these works collectively demonstrate that infants' are indeed sensitive to the expression of affect in infant-directed songs.

**5. Infant-Directed Speech and Song in Live Interactions**

In the caregiver-infant relationship, infant-directed speech and song act as vessels to convey emotional information to the prelingual infant, enhancing affective communication between both parties. By utilizing these channels, caregivers are able to express their own emotional state, stabilize infants' emotional cues, and connect with their infant (Persico et al., 2017; Fancourt & Perkins, 2018; Filippa et al., 2019). For the infant, ID speech and song may play slightly different roles towards a healthy attachment to their primary caregiver. While both modes can direct infants' focus, regulate arousal levels, and facilitate comprehension of key social cues, a handful of studies show that ID singing is significantly more effective at maintaining infants' attention than ID speech (Nakata & Trehub, 2004; Corbeil et al., 2016; Tsang et al., 2017). One explanation for these findings is that acoustically, ID speech may have less predictable pitch variability than ID singing, especially compared to lullabies (Falk, 2011; Audibert & Falk, 2018). Thus, while the temporal dynamics of ID speech may help infants link affect to spoken words, the captivating effects of ID singing may be more effective in soothing infants' and eliciting emotional connection. However, it's critical to note that the degree of affect in both ID speech and singing is modulated by infant state and response (Smith & Trainor, 2008;

Filippa *et al*., 2019). For instance, a mother's voice is perceived as more "emotional" and positive when the infant smiles or opens their eyes (Filippa et al., 2019). While ID speech and song have overlapping and distinctive functions, both reflect the bidirectionality of parent-infant relationship, and work to promote early emotional communication and connection (Figure 1).

With mutuality in mind, ID speech and song may enhance interpersonal synchrony between caregiver and infant (Savage *et al*., 2021). Biobehavioral synchrony in the caregiver-infant dyad is known to promote affiliative bonding and even predict infants' socioemotional outcomes (Feldman, 2007; Feldman, 2012; Savage et al., 2021). Child-parent synchrony has been observed in a variety of social contexts (Reindl et al., 2022; Kidby et al., 2023). One function worth exploring further is whether the quantity or qualities of ID speech and song influences moments of physiological, neural and/or behavioral synchrony between parent and infant. It's been shown that vocal communication is linked with coupled arousal levels in caregiver-infant dyads, and the arousal state of infants' directly impacts the amount of vocalizations produced by their caregiver in naturalistic settings (Wass et al., 2022). This underlines the prominence of reciprocal, affective communication in parent-infant interactions. Additional investigation is needed to determine whether the *type* of vocalization (i.e. ID speech or song) contributes to these coupling effects, and if so, what the social implications may be for the parent-infant relationship (Kokkinaki., 2017; Kokkinaki & Vasdekis, 2020; Markova et al., 2020). Moving forward, studying caregiver-infant interactions involving ID speech and song may benefit from synchronicity as a more accurate measure for bonding.

**6. Future Directions**

Examining early affective communication between caregivers and infants yields valuable insight into the bonding process. Current findings support ID speech and song as robust modes of affective communication, laying the groundwork for more naturalistic investigations into the parent-infant relationship. However, capturing all dimensions of affect expression in ID stimuli

while simultaneously measuring input (infant signals) and output (parental ID speech or song), may present complex data. Fortunately, recent progress in interpersonal data analysis has enhanced our capacity to address these inquiries more effectively (Wass et al., 2022; Turk et al., 2022; Kidby et al., 2023; Endevelt-Shapira & Feldman, 2023).

To test if ID speech and song serve as interpersonal mechanisms between an infant and their caregiver, we propose two aspects to guide future experiment design. First, is emulating the bidirectionality of affective communication between parent and infant. The response from one partner affects the response of the other, necessitating measures from both parties in a live, face-to-face interaction rather than recordings (Saint-Georges, 2013; Wass et al., 2022; Endevelt-Shapira & Feldman, 2023). Second, both ID speech and song are multimodal and involve much more than modified vocals; nonverbal behaviors such as affectionate touch, pointing, and gaze all contribute to the experience of ID speech, and presumably ID song. Thus, when evaluating the quality of a caregiver-infant relationship using ID speech vs. song stimuli, we propose inclusion of three key measures: (1) the caregiver's behavior, specifically their sensitivity or responsiveness to the infant's cues, (2) the infant's response, including at least one measure of arousal, and (3) interpersonal synchronization (behaviorally and/or physiologically) between the caregiver and the infant. While infant-directed (ID) singing has shown positive effects on parent-infant bonding, the impact of ID speech on the relationship necessitates deeper investigation, particularly in comparison to ID singing. Adopting an ecological approach to study parent-infant communication opens up opportunities to study theoretically important questions.

With music therapy being a growing line in clinical practice, the efficacy of ID speech versus song as interpersonal communication tools is a line worth exploring. One population of particular relevance may be caregivers facing maternal or postpartum depression, as symptoms can include reduced verbal engagement, flatter tone, and decreased responsiveness in vocalizations directed to infants (Lam-Cassettari & Kohlhoof, 2020; Morgan et al., 2021;

Brookman et al., 2023). Longitudinal work shows that maternal depression affects early bonding and can slow infants' social-emotional development (Tichelman et al., 2019; Priel et al., 2020). The emotive qualities of ID song have been shown to mediate these effects, but less is known about the impact of ID speech (de l'Etoile & Leider, 2011; de l'Etoile, 2012; Yang et al., 2019). Much work is still needed to understand just how these channels of ID communication differ in terms of enhancing the relationship and whether or not they are malleable via intervention, especially in clinical populations.

Emotional communication and reciprocity play a vital role in building the bond between caregivers and infants. The existing literature illustrates that infant-directed speech and song, two main forms of affective communication in early infancy, mirror the bidirectional nature of the parent-infant relationship and generate opportunities to connect during each interaction. Yet, a growing body of work highlights the need to empirically break down the multitude of emotive dimensions in both ID speech and song to identify how these modes of affective communication compare and contrast to each other, specifically in the early stages of the parent-infant relationship. Further investigating the social-emotional functions of ID vocalizations may lead to novel strategies in clinical and early care settings. These questions remain open for early development researchers to explore. Ultimately, the tools to build the parent-infant bond may rest in infant-directed communication.

## References

Abu-Zhaya, R., Seidl, A., & Cristia, A. (2017). Multimodal infant-directed communication: How caregivers combine tactile and linguistic cues. *Journal of Child Language*, *44*(5), 1088–1116. https://doi.org/10.1017/S0305000916000416

Ainsworth, M. D. S., Blehar, M. C., Waters, E., & Wall, S. (1978). *Patterns of attachment: A psychological study of the strange situation*. Lawrence Erlbaum.

Audibert, N., & Falk, S. (2018). Vowel space and f0 characteristics of infant-directed singing and speech. *Speech Prosody 2018*, 153–157. https://doi.org/10.21437/SpeechProsody.2018-31

Beebe, B., Jaffe, J., Markese, S., Buck, K., Chen, H., Cohen, P., Bahrick, L., Andrews, H., & Feldstein, S. (2010). The Origins of 12-Month Attachment: A Microanalysis of 4-Month Mother-Infant Interaction. *Attachment & Human Development*, *12*(0), 3–141. https://doi.org/10.1080/14616730903338985

Benders, T. (2013). Mommy is only happy! Dutch mothers' realisation of speech sounds in infant-directed speech expresses emotion, not didactic intent. *Infant Behavior and Development*, *36*(4), 847–862. https://doi.org/10.1016/j.infbeh.2013.09.001

Benoit, D. (2004). Infant-parent attachment: Definition, types, antecedents, measurement and outcome. *Paediatrics & Child Health*, *9*(8), 541–545.

Bergeson, T. R., & Trehub, S. E. (2002). Absolute Pitch and Tempo in Mothers' Songs to Infants. *Psychological Science*, *13*(1), 72–75. https://doi.org/10.1111/1467-9280.00413

Bowlby, J. (1969). *Attachment and loss: Attachment*. New York, NY: Basic Books.

Bowlby, J. (1982). Attachment and loss: Retrospect and Prospect. *American Journal of Orthopsychiatry*, 52(4), 664–678. https://doi.org/10.1111/j.1939-0025.1982.tb01456.x

Bowlby, J., & Ainsworth, M. (2013). The origins of attachment theory. Attachment theory: Social, developmental, and clinical perspectives, 45(28), 759-775.

Brand, R. J., Baldwin, D. A., & Ashburn, L. A. (2002). Evidence for 'motionese': Modifications in mothers' infant-directed action. *Developmental Science*, *5*(1), 72–83. https://doi.org/10.1111/1467-7687.00211

Brand, R. J., Shallcross, W. L., Sabatos, M. G., & Massie, K. P. (2007). Fine-Grained Analysis of Motionese: Eye Gaze, Object Exchanges, and Action Units in Infant-Versus Adult-Directed Action. *Infancy*, *11*(2), 203–214. https://doi.org/10.1111/j.1532-7078.2007.tb00223.x

Brookman, R., Kalashnikova, M., Levickis, P., Conti, J., Rattanasone, N. X., Grant, K.-A., Demuth, K., & Burnham, D. (2023). Effects of maternal depression on maternal responsiveness and infants' expressive language abilities. *PLOS ONE*, *18*(1), e0277762. https://doi.org/10.1371/journal.pone.0277762

Bryant, G. A., & Barrett, H. C. (2007). Recognizing Intentions in Infant-Directed Speech: Evidence for Universals. *Psychological Science*, *18*(8), 746–751. https://doi.org/10.1111/j.1467-9280.2007.01970.x

Carozza, S., & Leong, V. (2021). The Role of Affectionate Caregiver Touch in Early Neurodevelopment and Parent–Infant Interactional Synchrony. *Frontiers in Neuroscience*, *14*. https://www.frontiersin.org/articles/10.3389/fnins.2020.613378

Carvalho, M. E. S., Justo, J. M. R. M., Gratier, M., Tomé, T., Pereira, E., & Rodrigues, H. (2019). Vocal responsiveness of preterm infants to maternal infant-directed speaking and singing during skin-to-skin contact (Kangaroo Care) in the NICU. *Infant Behavior and Development*, *57*, 101332. https://doi.org/10.1016/j.infbeh.2019.101332

Chong, S. c. f., Werker, J. F., Russell, J. A., & Carroll, J. M. (2003). Three facial expressions mothers direct to their infants. *Infant and Child Development*, *12*(3), 211–232. https://doi.org/10.1002/icd.286

Cirelli, L. K., Einarson, K. M., & Trainor, L. J. (2014). Interpersonal synchrony increases prosocial behavior in infants. *Developmental Science*, *17*(6), 1003–1011. https://doi.org/10.1111/desc.12193

Cirelli, L. K., Jurewicz, Z. B., & Trehub, S. E. (2020). Effects of Maternal Singing Style on Mother–Infant Arousal and Behavior. *Journal of Cognitive Neuroscience*, *32*(7), 1213–1220. https://doi.org/10.1162/jocn_a_01402

Cirelli, L. K., & Trehub, S. E. (2018). Infants help singers of familiar songs. *Music & Science*, *1*, 205920431876162. https://doi.org/10.1177/2059204318761622

Corbeil, M., Trehub, S. E., & Peretz, I. (2013). Speech vs. singing: Infants choose happier sounds. *Frontiers in Psychology*, *4*. https://doi.org/10.3389/fpsyg.2013.00372

Corbeil, M., Trehub, S. E., & Peretz, I. (2016). Singing Delays the Onset of Infant Distress. *Infancy*, *21*(3), 373–391. https://doi.org/10.1111/infa.12114

Cristia, A. (2013). Input to Language: The Phonetics and Perception of Infant-Directed Speech. *Language and Linguistics Compass*, *7*(3), 157–170. https://doi.org/10.1111/lnc3.12015

Croy, I., Fairhurst, M. T., & McGlone, F. (2022). The role of C-tactile nerve fibers in human social development. *Current Opinion in Behavioral Sciences*, *43*, 20–26. https://doi.org/10.1016/j.cobeha.2021.06.010

de l'Etoile, S. K. (2006). Infant behavioral responses to infant-directed singing and other maternal interactions. *Infant Behavior and Development*, *29*(3), 456–470. https://doi.org/10.1016/j.infbeh.2006.03.002

de l'Etoile, S. K. (2012). Responses to infant-directed singing in infants of mothers with depressive symptoms. *The Arts in Psychotherapy*, *39*(5), 353–366. https://doi.org/10.1016/j.aip.2012.05.003

de l'Etoile, S. K., & Leider, C. N. (2011). Acoustic parameters of infant-directed singing in mothers with depressive symptoms. *Infant Behavior and Development*, *34*(2), 248–256. https://doi.org/10.1016/j.infbeh.2010.12.013

de Wolff, M. S., & van IJzendoorn, M. H. (1997). Sensitivity and Attachment: A Meta-Analysis on Parental Antecedents of Infant Attachment. *Child Development*, *68*(4), 571–591. https://doi.org/10.2307/1132107

DeCasper, A. J., Lecanuet, J.-P., Busnel, M.-C., Granier-Deferre, C., & Maugeais, R. (1994). Fetal reactions to recurrent maternal speech. *Infant Behavior and Development*, *17*(2), 159–164. https://doi.org/10.1016/0163-6383(94)90051-5

DeCasper, A. J., & Fifer, W. P. (1980). Of human bonding: Newborns prefer their mothers' voices. *Science, 208*(4448), 1174-1176. https://doi.org/10.1126/science.7375928

Ekman, P., Levenson, R. W., & Friesen, W. V. (1983). Autonomic Nervous System Activity Distinguishes Among Emotions. *Science*, *221*(4616), 1208–1210. https://doi.org/10.1126/science.6612338

Endevelt-Shapira, Y., & Feldman, R. (2023). Mother–Infant Brain-to-Brain Synchrony Patterns Reflect Caregiving Profiles. *Biology*, *12*(2), 284. https://doi.org/10.3390/biology12020284

Ettenberger, M., Bieleninik, Ł., Epstein, S., & Elefant, C. (2021). Defining Attachment and Bonding: Overlaps, Differences and Implications for Music Therapy Clinical Practice and Research in the Neonatal Intensive Care Unit (NICU). *International Journal of Environmental Research and Public Health*, *18*(4), 1733. https://doi.org/10.3390/ijerph18041733

Graven, S. N., & Browne, J. V. (2008). Auditory development in the fetus and infant. *Newborn and infant nursing reviews, 8*(4), 187-193. https://doi.org/10.1053/j.nainr.2008.10.010

Falk, S. (2011). Melodic versus intonational coding of communicative functions: A comparison of tonal contours in infant-directed song and speech. *Psychomusicology: Music, Mind and Brain*, *21*(1–2), 54–68. https://doi.org/10.1037/h0094004

Fancourt, D., & Perkins, R. (2018). The effects of mother–infant singing on emotional closeness, affect, anxiety, and stress hormones. *Music & Science*, *1*, 205920431774574. https://doi.org/10.1177/2059204317745746

Feldman, R. (2007). Parent–Infant Synchrony: Biological Foundations and Developmental Outcomes. *Current Directions in Psychological Science*, *16*(6), 340–345. https://doi.org/10.1111/j.1467-8721.2007.00532.x

Feldman, R. (2012). Parent-Infant Synchrony: A Biobehavioral Model of Mutual Influences in the Formation of Affiliative Bonds. *Monographs of the Society for Research in Child Development*, *77*(2), 42–51. https://doi.org/10.1111/j.1540-5834.2011.00660.x

Ferjan Ramírez, N., Weiss, Y., Sheth, K. K., & Kuhl, P. K. (2023). Parentese in infancy predicts 5-year language complexity and conversational turns. *Journal of Child Language*, 1–26. https://doi.org/10.1017/S0305000923000077

Fernald, A. (1989). Intonation and Communicative Intent in Mothers' Speech to Infants: Is the Melody the Message? *Child Development*, *60*(6), 1497–1510. https://doi.org/10.2307/1130938

Fernald, A. (1993). Approval and Disapproval: Infant Responsiveness to Vocal Affect in Familiar and Unfamiliar Languages. *Child Development*, *64*(3), 657–674. https://doi.org/10.2307/1131209

Fernald, A., & Kuhl, P. (1987). Acoustic determinants of infant preference for motherese speech. *Infant Behavior and Development*, *10*(3), 279–293. https://doi.org/10.1016/0163-6383(87)90017-8

Fernald, A., Taeschner, T., Dunn, J., Papousek, M., de Boysson-Bardies, B., & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language*, *16*(3), 477–501. https://doi.org/10.1017/S0305000900010679

Filippa, M., Monaci, M. G., & Grandjean, D. (2019). Emotion Attribution in Nonverbal Vocal Communication Directed to Preterm Infants. *Journal of Nonverbal Behavior*, *43*(1), 91–104. https://doi.org/10.1007/s10919-018-0288-1

Francis, A. L., & Oliver, J. (2018). Psychophysiological measurement of affective responses during speech perception. *Hearing Research*, *369*, 103–119. https://doi.org/10.1016/j.heares.2018.07.007

Frank MC, Alcock KJ, et al. Quantifying Sources of Variability in Infancy Research Using the Infant-Directed-Speech Preference. Advances in Methods and Practices in Psychological Science. 2020;3(1):24-52. https://doi.org/10.1177/2515245919900809

Ghazban, N. (2013). Emotion regulation in infants using maternal singing and speech (Version 1). *Toronto Metropolitan University*. https://doi.org/10.32920/ryerson.14645832.v1

Golinkoff, R. M., Can, D. D., Soderstrom, M., & Hirsh-Pasek, K. (2015). (Baby)Talk to Me: The Social Context of Infant-Directed Speech and Its Effects on Early Language Acquisition. *Current Directions in Psychological Science*, *24*(5), 339–344. https://doi.org/10.1177/0963721415595345

Groh, A. M., Fearon, R. M. P., Van IJzendoorn, M. H., Bakermans-Kranenburg, M. J., & Roisman, G. I. (2017). Attachment in the Early Life Course: Meta-Analytic Evidence for Its Role in Socioemotional Development. *Child Development Perspectives*, *11*(1), 70–76. https://doi.org/10.1111/cdep.12213

Grossmann, T. (2010). The development of emotion perception in face and voice during infancy. *Restorative Neurology & Neuroscience*, *28*(2), 219–236. https://doi.org/10.3233/RNN-2010-0499

Grossmann, T., Striano, T., & Friederici, A. D. (2005). Infants' electric brain responses to emotional prosody. *NeuroReport*, *16*(16), 1825–1828. https://doi.org/10.1097/01.wnr.0000185964.34336.b1

Gunnar, M. R., Brodersen, L., Nachmias, M., Buss, K., & Rigatuso, J. (1996). Stress reactivity and attachment security. *Developmental Psychobiology*, *29*(3), 191–204. https://doi.org/10.1002/(SICI)1098-2302(199604)29:3<191::AID-DEV1>3.0.CO;2-M

Hamilton, C. E. (2000). Continuity and Discontinuity of Attachment from Infancy through Adolescence. *Child Development*, *71*(3), 690–694. https://doi.org/10.1111/1467-8624.00177

Hepper, P. G., & Shahidullah, B. S. (1994). Development of fetal hearing. *Archives of Disease in Childhood Fetal and Neonatal Edition*, *71*(2), F81–F87.

Hilton, C. B., Moser, C. J., Bertolo, M., Lee-Rubin, H., Amir, D., Bainbridge, C. M., Simson, J., Knox, D., Glowacki, L., Alemu, E., Galbarczyk, A., Jasienska, G., Ross, C. T., Neff, M.

B., Martin, A., Cirelli, L. K., Trehub, S. E., Song, J., Kim, M., … Mehr, S. A. (2022). Acoustic regularities in infant-directed speech and song across cultures. *Nature Human Behaviour*, *6*(11), 1545–1556. https://doi.org/10.1038/s41562-022-01410-x

Jonsson, C.-O., Clinton, D., Fahrman, M., Mazzaglia, G., Novak, S., & Sörhus, K. (2001). How do mothers signal shared feeling-states to their infants? An investigation of affect attunement and imitation during the first year of life. *Scandinavian Journal of Psychology*, *42*(4), 377–381. https://doi.org/10.1111/1467-9450.00249

Kalashnikova, M., Carignan, C., & Burnham, D. (2017). The origins of babytalk: Smiling, teaching or social convergence? *Royal Society Open Science*, *4*(8), 170306. https://doi.org/10.1098/rsos.170306

Kao, C., Sera, M. D., & Zhanga, Y. (2022). Emotional Speech Processing in 3- to 12-Month-Old Infants: Influences of Emotion Categories and Acoustic Parameters. *Journal of Speech, Language, and Hearing Research*, *65*(2), 487–501. https://doi.org/10.1044/2021_JSLHR-21-00234

Kennell, J. H., & Klaus, M. H. (1984). Mother-infant bonding: Weighing the evidence. *Developmental Review*, *4*(3), 275–282. https://doi.org/10.1016/S0273-2297(84)80008-8

Kidby, S., Neale, D., Wass, S., & Leong, V. (2023). Parent–infant affect synchrony during social and solo play. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *378*(1875), 20210482. https://doi.org/10.1098/rstb.2021.0482

Kisilevsky, B. S., Hains, S. M. J., Brown, C. A., Lee, C. T., Cowperthwaite, B., Stutzman, S. S., Swansburg, M. L., Lee, K., Xie, X., Huang, H., Ye, H.-H., Zhang, K., & Wang, Z. (2009). Fetal sensitivity to properties of maternal speech and language. *Infant Behavior and Development*, *32*(1), 59–71. https://doi.org/10.1016/j.infbeh.2008.10.002

Kobak, R., Zajac, K., & Madsen, S. D. (2016). Attachment disruptions, reparative processes, and psychopathology: Theoretical and clinical implications. *Handbook of attachment: Theory, research, and clinical applications*, 25-39.

Kokkinaki, T. S., Vasdekis, V. g. s., Koufaki, Z. E., & Trevarthen, C. B. (2017). Coordination of Emotions in Mother–Infant Dialogues. *Infant and Child Development*, *26*(2), e1973. https://doi.org/10.1002/icd.1973

Kokkinaki, T., & Vasdekis, V. G. S. (2020). Beyond the Words: Comparing Interpersonal Engagement Between Maternal and Paternal Infant-Directed Speech Acts. *Frontiers in Psychology*, *11*, 523551. https://doi.org/10.3389/fpsyg.2020.523551

Kolacz, J., daSilva, E. B., Lewis, G. F., Bertenthal, B. I., & Porges, S. W. (2022). Associations between acoustic features of maternal speech and infants' emotion regulation following a social stressor. *Infancy*, *27*(1), 135–158. https://doi.org/10.1111/infa.12440

Koterba, E. A., & Iverson, J. M. (2009). Investigating motionese: The effect of infant-directed action on infants' attention and object exploration. *Infant Behavior and Development*, *32*(4), 437–444. https://doi.org/10.1016/j.infbeh.2009.07.003

Kuhl, P. K., Andruski, J. E., Chistovich, I. A., Chistovich, L. A., Kozhevnikova, E. V., Ryskina, V. L., Stolyarova, E. I., Sundberg, U., & Lacerda, F. (1997). Cross-Language Analysis of Phonetic Units in Language Addressed to Infants. *Science*, *277*(5326), 684–686. https://doi.org/10.1126/science.277.5326.684

Lam-Cassettari, C., & Kohlhoff, J. (2020). Effect of maternal depression on infant-directed speech to prelinguistic infants: Implications for language development. *PLoS ONE*, *15*(7), e0236787. https://doi.org/10.1371/journal.pone.0236787

Lavelli, M., & Fogel, A. (2013). Interdyad differences in early mother–infant face-to-face communication: Real-time dynamics and developmental pathways. *Developmental Psychology*, *49*(12), 2257–2271. https://doi.org/10.1037/a0032268

Lee, G. Y., & Kisilevsky, B. S. (2014). Fetuses respond to father's voice but prefer mother's voice after birth. *Developmental Psychobiology*, *56*(1), 1–11. https://doi.org/10.1002/dev.21084

Longhi, E. (2009). `Songese': Maternal structuring of musical interaction with infants. *Psychology of Music*, *37*(2), 195–213. https://doi.org/10.1177/0305735608097042

Markova, G., Nguyen, T., Schätz, C., & De Eccher, M. (2020). Singing in Tune – Being in Tune: Relationship Between Maternal Playful Singing and Interpersonal Synchrony: *Enfance*, *N° 1*(1), 89–107. https://doi.org/10.3917/enf2.201.0089

Masataka, N. (1999). Preference for infant-directed singing in 2-day-old hearing infants of deaf parents. *Developmental Psychology*, 35(4), 1001–1005. https://doi.org/10.1037/0012-1649.35.4.1001

Mastropieri, D., & Turkewitz, G. (1999). Prenatal experience and neonatal responsiveness to vocal expressions of emotion. *Developmental Psychobiology*, *35*(3), 204–214. https://doi.org/10.1002/(SICI)1098-2302(199911)35:3<204::AID-DEV5>3.0.CO;2-V

McMurray, B., Kovack-Lesh, K. A., Goodwin, D., & McEchron, W. (2013). Infant directed speech and the development of speech perception: Enhancing development or an unintended consequence? *Cognition*, *129*(2), 362–378. https://doi.org/10.1016/j.cognition.2013.07.015

Mesman, J., van IJzendoorn, M. H., & Bakermans-Kranenburg, M. J. (2009). The many faces of the Still-Face Paradigm: A review and meta-analysis. *Developmental Review*, *29*(2), 120–162. https://doi.org/10.1016/j.dr.2009.02.001

Milligan, K., Atkinson, L., Trehub, S. E., Benoit, D., & Poulton, L. (2003). Maternal attachment and the communication of emotion through song. *Infant Behavior and Development*, *26*(1), 1–13. https://doi.org/10.1016/S0163-6383(02)00165-0

Morgan, J. K., Santosa, H., Fridley, R. M., Conner, K. K., Hipwell, A. E., Forbes, E. E., & Huppert, T. J. (2021). Postpartum Depression Is Associated With Altered Neural Connectivity Between Affective and Mentalizing Regions During Mother-Infant Interactions. *Frontiers in Global Women's Health*, *2*. https://www.frontiersin.org/articles/10.3389/fgwh.2021.744649

Morningstar, M., Nelson, E. E., & Dirks, M. A. (2018). Maturation of vocal emotion recognition: Insights from the developmental and neuroimaging literature. *Neuroscience and Biobehavioral Reviews*, *90*, 221–230. https://doi.org/10.1016/j.neubiorev.2018.04.019

Nagy, E., Cosgrove, R., Robertson, N., Einhoff, T., & Orvos, H. (2022). Neonatal Musicality: Do Newborns Detect Emotions in Music? *Psychological Studies*. https://doi.org/10.1007/s12646-022-00688-1

Nakata, T., & Trehub, S. E. (2004). Infants' responsiveness to maternal speech and singing. *Infant Behavior and Development*, *27*(4), 455–464. https://doi.org/10.1016/j.infbeh.2004.03.002

Nakata, T., & Trehub, S. E. (2011). Expressive timing and dynamics in infant-directed and non-infant-directed singing. *Psychomusicology: Music, Mind and Brain*, *21*(1–2), 45–53. https://doi.org/10.1037/h0094003

Naoi, N., Minagawa-Kawai, Y., Kobayashi, A., Takeuchi, K., Nakamura, K., Yamamoto, J., & Kojima, S. (2012). Cerebral responses to infant-directed speech and the effect of talker familiarity. *NeuroImage*, *59*(2), 1735–1744. https://doi.org/10.1016/j.neuroimage.2011.07.093

Nguyen, T., Flaten, E., Trainor, L. J., & Novembre, G. (2023). Early social communication through music: State of the art and future perspectives. *Developmental Cognitive Neuroscience*, *63*, 101279. https://doi.org/10.1016/j.dcn.2023.101279

Papoušek, M. (2007). Communication in early infancy: An arena of intersubjective learning. *Infant Behavior and Development*, *30*(2), 258–266. https://doi.org/10.1016/j.infbeh.2007.02.003

Papoušek, M., Papoušek, H., & Symmes, D. (1991). The meanings of melodies in motherese in tone and stress languages. *Infant Behavior and Development*, *14*(4), 415–440. https://doi.org/10.1016/0163-6383(91)90031-M

Persico, G., Antolini, L., Vergani, P., Costantini, W., Nardi, M. T., & Bellotti, L. (2017). Maternal singing of lullabies during pregnancy and after birth: Effects on mother–infant bonding and on newborns' behaviour. Concurrent Cohort Study. *Women and Birth*, *30*(4), e214–e220. https://doi.org/10.1016/j.wombi.2017.01.007

Raby, K. L., Roisman, G. I., Fraley, R. C., & Simpson, J. A. (2015). The Enduring Predictive Significance of Early Maternal Sensitivity: Social and Academic Competence Through Age 32 Years. *Child Development*, *86*(3), 695–708. https://doi.org/10.1111/cdev.12325

Ranson, K. E., & Urichuk, L. J. (2008). The effect of parent–child attachment relationships on child biopsychosocial outcomes: A review. *Early Child Development and Care*, *178*(2), 129–152. https://doi.org/10.1080/03004430600685282

Reindl, V., Wass, S., Leong, V., Scharke, W., Wistuba, S., Wirth, C. L., Konrad, K., & Gerloff, C. (2022). Multimodal hyperscanning reveals that synchrony of body and mind are distinct in mother-child dyads. *NeuroImage*, *251*, 118982. https://doi.org/10.1016/j.neuroimage.2022.118982

Rock, A. M. L., Trainor, L. J., & Addison, T. L. (1999). Distinctive messages in infant-directed lullabies and play songs. *Developmental Psychology*, *35*(2), 527–534. https://doi.org/10.1037/0012-1649.35.2.527

Saint-Georges, C., Chetouani, M., Cassel, R., Apicella, F., Mahdhaoui, A., Muratori, F., Laznik, M.-C., & Cohen, D. (2013). Motherese in Interaction: At the Cross-Road of Emotion and Cognition? (A Systematic Review). *PLOS ONE*, *8*(10), e78103. https://doi.org/10.1371/journal.pone.0078103

Santesso, D. L., Schmidt, L. A., & Trainor, L. J. (2007). Frontal brain electrical activity (EEG) and heart rate in response to affective infant-directed (ID) speech in 9-month-old infants. *Brain and Cognition*, *65*(1), 14–21. https://doi.org/10.1016/j.bandc.2007.02.008

Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., & Fitch, W. T. (2021). Music as a coevolved system for social bonding. *Behavioral and Brain Sciences*, *44*, e59. https://doi.org/10.1017/S0140525X20000333

Schore, A. N. (2001). Effects of a secure attachment relationship on right brain development, affect regulation, and infant mental health. *Infant Mental Health Journal*, *22*(1–2), 7–66. https://doi.org/10.1002/1097-0355(200101/04)22:1<7::AID-IMHJ2>3.0.CO;2-N

Schwarz, I.-C., Marklund, E., Marklund, U., Gustavsson, L., & Lam-Cassettari, C. (2023). Affect in Infant-Directed Speech of Swedish-Speaking Mothers and Fathers to 3-, 6-, 9-, and 12-Month-Old Infants. *Language Learning and Development*, 1–13. https://doi.org/10.1080/15475441.2023.2239801

Shepard, K. G., Spence, M. J., & Sasson, N. J. (2012). Distinct Facial Characteristics Differentiate Communicative Intent of Infant-Directed Speech. *Infant and Child Development*, *21*(6), 555–578. https://doi.org/10.1002/icd.1757

Singh, L., Morgan, J. L., & Best, C. T. (2002). Infants' Listening Preferences: Baby Talk or Happy Talk? *Infancy*, *3*(3), 365–394. https://doi.org/10.1207/S15327078IN0303_5

Smith, N. A., & Trainor, L. J. (2008). Infant-Directed Speech Is Modulated by Infant Feedback. *Infancy*, *13*(4), 410–420. https://doi.org/10.1080/15250000802188719

Soderstrom, M. (2007). Beyond babytalk: Re-evaluating the nature and content of speech input to preverbal infants. *Developmental Review*, *27*(4), 501–532. https://doi.org/10.1016/j.dr.2007.06.002

Spinelli, M., Fasolo, M., & Mesman, J. (2017). Does prosody make the difference? A meta-analysis on relations between prosodic aspects of infant-directed speech and infant outcomes. *Developmental Review*, *44*, 1–18. https://doi.org/10.1016/j.dr.2016.12.001

Stern, D. N. (1974). Mother and infant at play: The dyadic interaction involving facial, vocal, and gaze behaviors. In M. Lewis & L. A. Rosenblum, *The effect of the infant on its caregiver*. Wiley-Interscience.

Sullivan, R., Perry, R., Sloan, A., Kleinhaus, K., & Burtchen, N. (2011). Infant bonding and attachment to the caregiver: Insights from basic and clinical science. *Clinics in Perinatology*, *38*(4), 643–655. https://doi.org/10.1016/j.clp.2011.08.011

Tichelman, E., Westerneng, M., Witteveen, A. B., Baar, A. L. van, Horst, H. E. van der, Jonge, A. de, Berger, M. Y., Schellevis, F. G., Burger, H., & Peters, L. L. (2019). Correlates of prenatal and postnatal mother-to-infant bonding quality: A systematic review. *PLOS ONE*, *14*(9), e0222998. https://doi.org/10.1371/journal.pone.0222998

Trainor, L. J. (1996). Infant preferences for infant-directed versus noninfant-directed playsongs and lullabies. *Infant Behavior and Development*, *19*(1), 83–92. https://doi.org/10.1016/S0163-6383(96)90046-6

Trainor, L. J., Austin, C. M., & Desjardins, R. N. (2000). Is Infant-Directed Speech Prosody a Result of the Vocal Expression of Emotion? *Psychological Science*, *11*(3), 188–195. https://doi.org/10.1111/1467-9280.00240

Trainor, L. J., Clark, E. D., Huntley, A., & Adams, B. A. (1997). The acoustic basis of preferences for infant-directed singing. *Infant Behavior and Development*, *20*(3), 383–396. https://doi.org/10.1016/S0163-6383(97)90009-6

Trehub, S. E., Ghazban, N., & Corbeil, M. (2015). Musical affect regulation in infancy: Musical affect regulation in infancy. *Annals of the New York Academy of Sciences*, *1337*(1), 186–192. https://doi.org/10.1111/nyas.12622

Trehub, S. E., Plantinga, J., & Russo, F. A. (2016). Maternal Vocal Interactions with Infants: Reciprocal Visual Influences: Maternal Speech and Singing. *Social Development*, *25*(3), 665–683. https://doi.org/10.1111/sode.12164

Trehub, S. E., Unyk, A. M., Kamenetsky, S. B., Hill, D. S., Trainor, L. J., Henderson, J. L., & Saraza, M. (1997). Mothers' and fathers' singing to infants. *Developmental Psychology, 33*(3), 500–507. https://doi.org/10.1037//0012-1649.33.3.500

Tronick E. Z. (1989). Emotions and emotional communication in infants. T*he American psychologist, 44*(2), 112–119. https://doi.org/10.1037//0003-066x.44.2.112

Tsang, C. D., Falk, S., & Hessel, A. (2017). Infants Prefer Infant-Directed Song Over Speech. *Child Development*, *88*(4), 1207–1215.

Turk, E., Endevelt-Shapira, Y., Feldman, R., van den Heuvel, M. I., & Levy, J. (2022). Brains in Sync: Practical Guideline for Parent–Infant EEG During Natural Interaction. *Frontiers in Psychology*, *13*. https://www.frontiersin.org/articles/10.3389/fpsyg.2022.833112

Wass, S., Phillips, E., Smith, C., Fatimehin, E. O., & Goupil, L. (2022). Vocal communication is tied to interpersonal arousal coupling in caregiver-infant dyads. *eLife*, *11*, e77399. https://doi.org/10.7554/eLife.77399

Waters, E., Merrick, S., Treboux, D., Crowell, J., & Albersheim, L. (2000). Attachment Security in Infancy and Early Adulthood: A Twenty-Year Longitudinal Study. *Child Development*, *71*(3), 684–689. https://doi.org/10.1111/1467-8624.00176

Yan, R., Jessani, G., Spelke, E. S., de Villiers, P., de Villiers, J., & Mehr, S. A. (2021). Across demographics and recent history, most parents sing to their infants and toddlers daily. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *376*(1840), 20210089. https://doi.org/10.1098/rstb.2021.0089

Yang, W., Bai, Y., Qin, L., Xu, X., Bao, K., Xiao, J., & Ding, G. (2019). The effectiveness of music therapy for postpartum depression: A systematic review and meta-analysis. *Complementary Therapies in Clinical Practice*, *37*, 93–101. https://doi.org/10.1016/j.ctcp.2019.09.002