The Ins and Outs of Baby Talk

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It is usually no secret when there is a baby in the room. Infants attract our attention, and we immediately and instinctively change our speech when we engage with them. "Baby talk" fills the air. This distinct speech register, also known as *motherese* or more formally as *infant-directed speech* (IDS), has been observed across diverse languages and cultures. Babies demonstrate a clear preference for IDS. The strong endorsement of IDS by infants continues to fuel the curiosity of scientists, clinicians, and caregivers about this common speech form and how it shapes infant development.

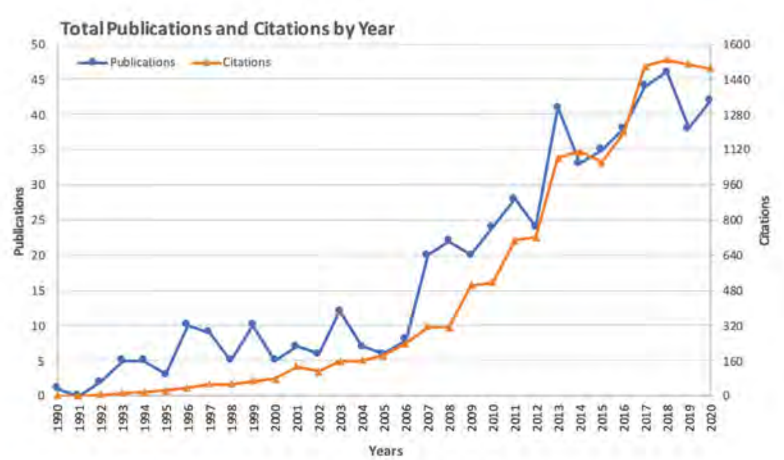
In the research world, "infant" is often defined as a child under 2 years of age. In recent years, scientific interest in IDS has increased dramatically. **Figure 1** shows that the number of publications on the topic of IDS and citations of this work increased markedly since 2006. In 2019, the Acoustical Society of America sponsored two well-attended special sessions devoted to IDS (see acousticstoday.org/ASA177TuesAbstracts, pages 1728-1731 and 1763-1767). IDS is undeniably a hot topic.

Although producing IDS with a baby is a simple and natural task, researchers have worked long and hard to describe the distinct acoustic properties of IDS. This article shows that a great deal of progress has been made. Some acoustic properties of IDS, including aspects of vocal pitch and rhythm, are now well-established. Other acoustic properties that pertain to the vocal resonances of the speech signal, are less well understood and are currently a focus of intense research attention and debate. Explaining exactly how specific properties of IDS impact infant development is another challenge that continues to drive research activity. In this article, we also outline some of the knowledge gaps that are energizing researchers to reach for a deeper understanding of the unique acoustic properties of IDS and to explore how IDS is connected with infant speech. As we learn more about IDS and why babies thrive on it, we are also finding ways to leverage this knowledge to promote infant development.

Infants Prefer Infant-Directed Speech

IDS has captivated scientists precisely because it is so effective in enticing infant attention. Across many studies in

Figure 1. *Publications (**blue**) and citations (**orange**) of papers on infant-directed speech (IDS) from 1990 to 2020. From the Web of Science.*



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which infants are presented a choice to listen to samples of IDS and adult-directed speech (ADS), infants (even newborns) repeatedly show a clear and strong preference to listen to IDS, with few studies deviating from this pattern. A meta-analysis found that the average listening time difference between IDS and ADS (or "the effect size of IDS preference" in statistical terms) was significant and large (Dunst et al., 2012).

Infant preference for IDS, being recognized as one of the most robust behaviors measured in infancy, was selected as the target behavior in a large-scale study designed to understand how subject variables and testing methodologies affect the measurement of infant behavior. This study, conducted by the ManyBabies Consortium, involved 67 laboratories across North America, Europe, Australia, and Asia. The findings provided further conclusive evidence of infants' preference for IDS over ADS (ManyBabies Consortium, 2020). There is no doubt that infants are attracted to IDS.

Acoustic Properties of Infant-Directed Speech

What is it about IDS that babies like? Studies show that when caregivers talk to their infant, they modify their speech on multiple levels. This includes basic speech patterns that play a broad role in communication and can be observed across different languages (conveying emotion and talker information and basic units such as vowels, consonants, and word forms) as well as acoustic cues that mark specific lexical, grammatical, and pragmatic features that are important in a specific language. Our focus here is on basic acoustic speech patterns that have a broad impact and are more likely to be universal across languages.

To understand the acoustic properties of IDS, it is useful to know that the acoustic speech signal has two independent components, referred to as the source and the filter. The vocal source component is determined by how fast the vocal folds vibrate, which determines the voice pitch or fundamental frequency (see article on singing by Sundberg et al. on pages 43-51). The voice pitch of an infant or child is much higher than that of an adult because their short, light vocal folds vibrate faster compared with the longer and thicker vocal folds of an adult. Talkers also vary their voice pitch by adjusting the tension of the vocal folds.

The vocal filter component refers to the effects of the length and shape of the vocal tract, the term used to refer to the tube formed by the vocal folds on one end and the mouth at the other end. Movements of the tongue, jaw, and lips vary the length and shape of the vocal tract, which determines the resonances of the vocal tract.

The acoustic patterns formed by the vocal resonances created when we speak are referred to as formants and are numbered in ascending frequency value (the lowest is the 1st formant [F1], next is the 2nd formant [F2], etc.). The formants are essentially narrow frequency regions where acoustic energy is increased because these frequencies vibrate most easily within the associated vocal tract space. The first three formants contain critical acoustic information for speech communication.

The vocal resonances and associated formant frequencies are higher for the short vocal tract of an infant or child compared with the longer vocal tract of an adult. Talkers modify the resonance of the vocal tract to create different vowel sounds by moving their articulators to create different vocal tract shapes, such as by adjusting the degree and location of constrictions along the vocal tract.

An extensive body of research has concentrated on describing the acoustic structure of IDS. This work has considered each component, typically by comparing samples of IDS with comparable samples of ADS (Soderstrom, 2007).

Voice Pitch and Rhythmic Properties of Infant-Directed Speech

The distinct vocal source properties of IDS are well-established (see **Multimedia** 1-5 at acousticstoday.org/polkamedia for audio examples in English and in Turkish; see video example at bit.ly/3m3ecHh). Overall, higher voice pitch, wider voice pitch range and greater pitch variability have been found in IDS (compared with ADS) in a variety of languages, including both nontonal languages (Fernald et al., 1989) and tonal languages (Liu et al., 2009). Several studies have shown that high voice pitch is the primary acoustic determinant of the infants' preference for IDS (Fernald and Kuhl, 1987; Leibold and Werner, 2007). Research focused on the speech movements that occur during IDS have observed, as expected, that adults produce faster vocal fold vibrations and also raise their larynx when they talk to young infants (Ogle and Maidment, 1993; Kalashnikova et al., 2017). Larynx raising naturally occurs when vocal fold tension increases (which raises voice pitch) and can also shorten the overall vocal tract length.

It is widely held that the primary goal or intention guiding these characteristic voice pitch properties is conveying emotion to the young infant (Saint-Georges et al., 2013). Understanding the emotional expression in IDS led researchers to explore the pitch contours found in IDS. Fernald and Simon (1984) observed that most utterances in IDS had either rising or falling pitch contours. Stern and colleagues (1982) identified the social and linguistic context where these pitch contours were used. For example, a rising contour was frequently used when mothers tried to engage in eye contact with an inattentive baby. Studies also show that creating "happy talk" is the fundamental goal of IDS and that positive affect is what drives infant preference (Singh et al., 2002). Thus, understanding pitch contours in IDS can help us decode the affective function of IDS.

In terms of rhythmic features, IDS universally contains shorter utterances and longer pauses between words; in some languages, including English and Japanese, there is also an enhanced lengthening of words or syllables at the end of a phrase or utterance (Fernald et al., 1989; Martin et al., 2016). This is helpful because natural fluent speech typically lacks pauses between words, something you notice when encountering an entirely foreign language. This also highlights an initial challenge for babies, learning which speech patterns are reoccurring words, aka word segmentation. Infants begin to acquire word segmentation skills at around 6 months, through experience listening to a specific language and before they attach meaning to each word they hear (Jusczyk, 1999).

Overall, the tempo of IDS provides the infant with a speech stream that is easier to track with clearer cues marking word boundaries and other syntactic units. Consistent with this, the most prominent rhythm in the acoustic speech signal, which matches the timing of stressed syllables, was observed to be stronger in IDS compared with ADS (Leong et al., 2017). This speech rhythm was also prominent (and synchronized) in mother and infant brain patterns when they watched a nursery rhyme video together (Santamaria et al., 2020).

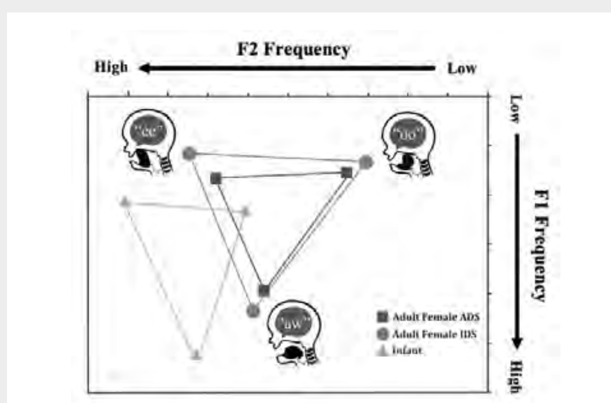
The enhanced temporal properties of IDS likely explains the positive effects of IDS on infant speech processing. For example, IDS facilitates infant word segmentation performance (Thiessen et al., 2005), an important language-specific speech-processing skill that emerges in infancy and supports early word learning. The list of the positive effects of IDS rhythm on speech processing, which includes supporting better discrimination and tracking of syllable patterns and detection of speech in noise, continues to grow (Soderstrom, 2007).

Vocal Resonance Properties of Infant-Directed Speech

Research on IDS has also considered the other fundamental component of speech, the filter or resonance properties. The focus here has been on vowel sounds. Early research by Kuhl and colleagues (1997) reported that vowels are produced in an exaggerated form in IDS; this *hyperarticulation* of vowels expands the vowel space, a standard graphic display that captures how vowel articulation and formant patterns are related.

In the classic vowel space (**Figure 2**), F1 increases as the tongue/jaw height decreases and F2 increases as the tongue constriction moves to the front of the mouth. Importantly, three vowel sounds found in every spoken language, "ee," "aw," and "oo," form the corners of this F1/F2 vowel space. These corner vowels are associated with gestural extremes that define the full range of movements that we use to create vowel sounds: "ee" has the most high and front constriction of the vocal tract, "oo" has the most high and back constriction of the vocal tract, and "aw" has the most open and unconstricted posture of the vocal tract. All other vowel sounds fall within the limits defined by these corner vowel sounds.

Figure 2. *The articulatory/acoustic vowel space corresponding to vowels produced by an adult female in ADS (**squares**) and in IDS (**circles**), and by an infant (**triangles**). F1 and F2, 1st and 2nd formants, respectively.*



The finding that the vowel space is larger, with the corner vowels spaced further apart in IDS compared with ADS, is also illustrated schematically in **Figure 2**.

Increasing the acoustic distance between vowels enhances recognition of distinct vowel sounds. Moreover, even in ADS, a larger vowel space is typically associated with more intelligible speech (Bradlow et al., 1996). An expanded vowel space was observed for IDS vowels produced in several languages, suggesting this is a universal feature of IDS (Kuhl et al., 1997). Moreover, infants with a mother who expanded her vowel space when producing IDS also performed better in a speech sound discrimination task (Liu et al., 2009). Other work suggests that early exposure to vowel expansion in IDS is associated with better expressive and receptive language skills at two years (Hartman et al., 2016).

The idea that caregivers expand their vowel space to make speech clearer is consistent with the finding that adults do not expand their vowel space when speaking to a pet with little or no capacity for acquiring language skills even though pet-directed speech typically contains the characteristic pitch properties of IDS that convey affect as outlined above (Burnham et al., 2002). IDS appears to be a form of hyperarticulated speech that promotes language development by clarifying and enhancing speech segments (e.g., vowels and consonants).

We now see this view as incomplete. As work advanced, an expanded vowel space in IDS has not been found in all languages, in all interactions, or at all infant ages (see Hartman et al., 2016). Vowel expansion has also been absent when studies relied on samples of natural spontaneous speech instead of the structured laboratory-recorded samples used in earlier studies (Martin et al., 2015). In a study of IDS in Japanese, Miyazawa and colleagues (2017) observed vowel space expansion when average formant values were considered. However, the IDS vowel sounds were actually not more distinct because there was much more acoustic variability and overlap among different vowels produced in IDS, which makes recognizing distinct vowel sounds more, not less, difficult.

Actually, some researchers suggested that vowel space expansion in IDS is an unintended side effect of the increased pitch (which also raises the larynx and shortens the vocal tract) and slower speaking rate that characterizes this speech style rather than being shaped by the parents' direct effort to clarify speech patterns (McMurray et al., 2013). For example, in her study of IDS in Dutch, Benders (2013) observed a reduced rather than an expanded vowel space, and she also observed an overall rise in all formant frequencies for IDS vowels relative to ADS vowels. This pattern is noteworthy given that smiling, which shortens the vocal tract length, is known to shift formants upward and further apart in frequency (Shor, 1978). Thus, Benders claimed that caregivers modify their vowel sounds in IDS, especially with young infants, to communicate positive emotion rather than to provide clearer speech. Meanwhile, Miyazawa and colleagues (2017) observed that IDS had a breathier voice quality compared with ADS vowels, an effect also associated with communicating emotion.

Yet another perspective emerged from a study by Kalashnikova and colleagues (2017) that directly examined the tongue and lip movements that caregivers make when they produce IDS and ADS, which are the source of these formant patterns. In this study, special sensors were strategically placed on eight moms to track their lip and tongue movements while they produced IDS with their 11-month-old infants and ADS with the experimenter. Surprisingly, when the moms produced the corner vowels in IDS, their tongue and lips movements were not exaggerated or hyperarticulated as the researchers expected, even though simultaneous acoustic recordings showed expansion of the IDS vowel space.

Through an analysis that combined lip movement and vowel formant measures, Kalashnikova et al. (2017) inferred that the IDS speech was produced with a shorter vocal tract and higher pitch, which mothers can create by raising their larynx. They concluded that expansion of the F1/F2 acoustic vowel space in IDS is not created by the mother's intentional efforts to produce clearer vowel sounds using exaggerated articulatory movements. Instead, mothers are speaking with the unintentional purpose of sounding smaller and thus unthreatening and nonaggressive.

This speaking style can also be viewed as the mother trying to imitate her infant. Moreover, this form of *vocal social convergence* is observed in other species and is regarded as a mechanism for creating a close emotional bond between adult and infant, presumably to ensure that infant offspring survive and thrive. Kalashnikova et al. (2017) claim that in early infancy, any benefits of IDS related to clarifying speech units are secondary to this basic social/emotional bonding goal, and, as in evolution, these linguistically motivated patterns likely emerge later in development and piggy-back on to this social bonding function.

Overall, what is happening to the resonance component of the speech signal when caregivers use IDS is not fully resolved. Caregivers may be modifying their speech to clarify speech units and boost language development, to convey positive emotions, to sound smaller and build social bonds, or some combination of these effects. Although the details remain unclear, understanding how these modifications impact infant development continues to ignite and steer ongoing research.

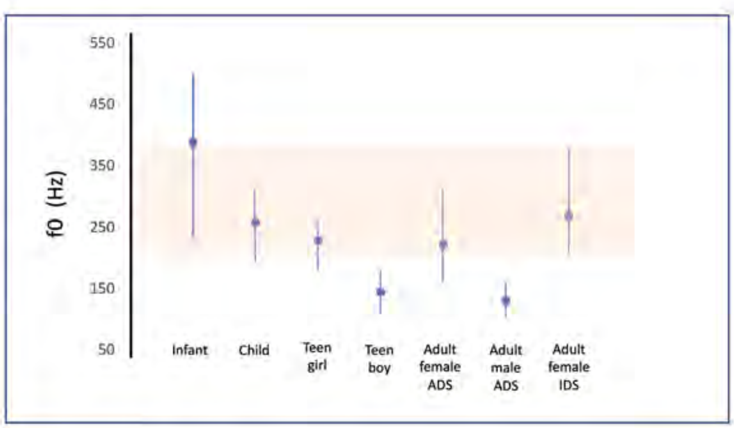
Infant-Directed Speech and Infant Speech: An Important Connection?

As outlined in **Vocal Resonance Properties of Infant-Directed Speech**, there are different viewpoints regarding what motivates the use of IDS. One idea to emerge recently is that when mothers use IDS, they are altering their speech to sound smaller and more like an infant. Although this is a new perspective on IDS, the act of unconsciously adapting your speech to mirror or imitate features of your conversational partner is not a new observation. This has been noted and studied extensively in adult speech communication and is often referred to as *phonetic convergence*. Moreover, in adult-to-adult interaction, speech convergence is typically associated with liking or holding a positive attitude toward your conversational partner (Pardo, 2013).

Other findings point to an important connection between IDS and infant speech. First, there are indeed clear parallels between IDS and infant speech. With respect to vocal source properties, infant speech and IDS have similar voice pitch values, particularly when IDS is produced by a female adult/mother. **Figure 3** shows voice pitch values across the life span, including voice pitch values for IDS produced by female adults. **Figure 3**, *pink box*, highlights the range in which voice pitch values overlap across infant speech and speech produced by an adult female using IDS.

Although voice pitch values can overlap across IDS and infant speech, the vocal filter properties of infant speech and IDS are more distinct. When an adult female raises her larynx and spreads her lips to shorten her vocal tract length, she will sound like a smaller person. Nevertheless, a mother cannot shorten her vocal tract enough to match the vocal tract length of her infant. Infant speech has much higher vocal resonances, reflected in the formant frequencies uniquely associated with a talker with a very short vocal tract. This results in higher formant frequency values for infant speech compared with adult speech which are shown by a spectrogram of the vowel "ee" produced by an infant and a female adult (**Figure 4**). These differences are also apparent in the vowel space shown in **Figure 2**, where you can see that the corner

Figure 3. *Typical average voice pitch (f0) values for speakers across the life span. Blue lines, observed range of values observed within each group. Pink box, voice pitch range where infant and adult female IDS values overlap. Data from Masapollo et al., 2016, Table 1.*



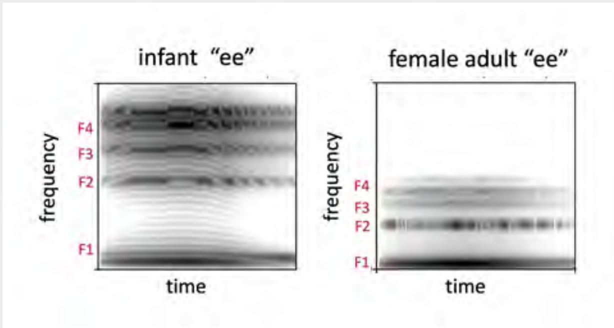


Figure 4. *Example spectrograms of "ee" vowels showing the formant patterns produced by an infant (**left**) and an adult female (**right**).*

vowels found in infant speech are acoustically distinct from those found in adult female ADS or IDS vowels. That being said, when mothers use IDS, they do their best to alter each component of speech to approximate or converge with the properties of an infant talker.

Notably, these changes in IDS align very well with what infants like when it comes to speech. Infants not only favor IDS, they also are attracted to infant speech. In listening preference tests, young infants listened longer to vowels sounds produced by an infant over vowel sounds produced by a female adult (Masapollo et al., 2016). To measure this, researchers created vowel sounds that simulate a 6-month-old talker using a special speech synthesizer (examples are shown in **Figure 4**). This study also showed that infants prefer each component of infant speech; infants prefer the high voice pitch of an infant and also the high-frequency vocal resonances produced by a small-infant vocal tract. Importantly, this means that infants have a distinct preference for infant talkers; they are not simply favoring a high voice pitch that is known to be an attractive property of IDS.

It was also noted in this study (Masapollo et al., 2016) that some infants vocalized and smiled more when they listened to infant vowel sounds compared with adult vowel sounds, suggesting that the strong attraction to infant speech may stimulate and reward vocal exploration in young infants. Another study (Polka et al., 2014) examined the infants' ability to recognize the same vowel when it is produced by different talkers (e.g., man, woman, child, and infant). Including infant vowel sounds in this task made it more challenging, but it also boosted infant listening times and recognition performance (Polka et al., 2014). It seems that infant speech sounds grab and hold infant attention in ways that help babies recognize important speech categories. Overall, these findings suggest that vocal convergence in IDS may play a broader role beyond social bonding. Vocal convergence may also help the infant discover that their own vocalizations are part of this vocal social space and motivate them to explore and refine their vocal skills.

Infants' attraction to infant speech sounds raises new questions. Are mothers instinctively aware of this bias? Does this motivate them to sound more infant-like when using IDS? Then again, maybe mothers are shaping this bias by using vocal convergence? Is there an important connection between IDS and infant speech that will help us understand how infants acquire spoken language? These intriguing questions drive current research and promise to shed new light on the role of IDS in infant development.

Multitasking with Infant-Directed Speech

Although we have learned a great deal about the acoustic properties of IDS and how it affects infant speech processing, we are just beginning to understand how IDS impacts infant development. As noted in **Vocal Pitch and Rhythmic Properties of Infant-Directed Speech**, **Vocal Resonance Properties of Infant-Directed Speech**, and **Infant-Directed Speech and Infant Speech: An Important Connection?**, a range of functions for IDS has been proposed, including attracting and holding infant attention, highlighting and enhancing linguistic segments and structure, communicating emotion, strengthening infant/caregiver social bonds, and stimulating vocal exploration (Saint-Georges et al., 2013; Golinkoff et al., 2015).

It is widely agreed that IDS is a powerful multitasking tool that caregivers flexibly adapt to meet the moment-to-moment needs of their infant. This adaptability is ideal for meeting parent and infant needs but presents challenges for scientific investigation. In specific contexts, the diverse functions shaping IDS are often intertwined in complex ways (Saint-Georges et al., 2013). For example, modifications that communicate positive affects can promote social bonding while also facilitating speech processing by enhancing attention.

Moreover, these different functions are not equally prominent in any given interaction or across all ages or developmental stages. For example, in IDS with young infants (<12 months), communicating emotion is often more prominent than clarifying linguistic structures. In IDS with older children (>12 months), the reverse occurs, such that highlighting linguistic structure is often more prominent than communicating emotion and building social bonds. No doubt, IDS is best understood in the context of infant/caregiver interaction and when the needs of the child and the intentions of the caregiver are identified.

Contingency and Synchrony Are Fundamental

IDS is recognized to be dynamic and actively shaped by both the infant and caregiver. Contingent and synchronized responding between mother and infant is a core feature of IDS. Although an IDS speaking style can be simulated by an adult, IDS production is facilitated by the presence of a baby. The salience of caregiver responsiveness is demonstrated by the finding that adults can readily identify audio recordings of IDS recorded with and without an infant present (Trehub et al., 1997).

Saint-Georges and colleagues (2013) proposed that IDS creates an interactive communication loop connecting the infant and the caregiver in a synergistic way. This idea has motivated researchers to search for physiological markers of enhanced synchrony during IDS. Synchronous activity has been observed in heart rate and respiration measures (McFarland et al., 2019) and gaze patterns (Santamaria et al., 2020) recorded during parent/infant interactions where IDS is commonly used.

The powerful role of dynamic social interaction is also reinforced by research showing that infants can readily learn to discriminate consonants from a foreign language in a live interaction involving IDS but not from audiovisual recordings (Kuhl et al., 2003). It is also intriguing to consider how the musical quality of IDS (which is enhanced in infant-directed singing) shapes this parent-infant synchrony, given that early music exposure affects infant brain development (Zhao and Kuhl, 2020).

The critical role of IDS contingency and synchrony is also supported by evidence that challenges on each side of the interactional loop affect the synergistic connection created via IDS. For example, from the caregiver side, mothers with depression tend to include less affective information and have smaller pitch variations when speaking to their infants (Kaplan et al., 2001). Infants' learning is affected when maternal depression persists over an extended period (Kaplan et al., 2011). However, infants of depressed mothers remain responsive to IDS from nondepressed fathers and the quality of IDS is soon improved when the mother's depression is lifted (Kaplan et al., 2004). On the infant side, the preference for IDS is absent or reduced among children with autism spectrum disorder, presumably reflecting difficulties in processing the heightened emotional content of IDS (Kuhl et al., 2005).

New Directions

Going forward, research is moving quickly to expand our knowledge of IDS. Although we have learned a great deal about the acoustic properties of IDS, we need to learn more about the speech movements that give rise to IDS signals. This type of work is technically challenging but critical for understanding exactly what caregivers are doing when they adapt their speech for their infant, especially with respect to vocal resonance properties.

Future research will also continue to build a more complete understanding of the social, emotional, cognitive, and linguistic benefits of IDS for the developing child. Research exploring the physiological responses of interacting caregivers and infants will play a central role by helping us identify and understand the contingent and synchronous processes that are mediated by IDS. Each new finding pushes our curiosity to a higher level. We are confident that IDS will hold the interest of infants, caregivers, and scientists for a long time and can help us understand conditions that compromise parent/infant connection and identify new ways to optimize infant development.

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