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Department of Brain and Behavioral Sciences (DBBS)
MSc in Psychology, Neuroscience and Human Sciences

Prosodic Features of Infant-Directed Speech and Interactive Behavior in Mothers of Infants with Visual Impairment: An Exploratory Study

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Table of Contents

Abstract

The maternal voice is a primary auditory stimulus in early development and can be detected in utero as early as 23-34 weeks of gestation (Kisilevsky & Hains, 2011). After birth, caregivers naturally adapt their speech when interacting with infants, producing Infant-Directed Speech (IDS), also known as baby talk, motherese, or parentese. Compared to Adult-Directed Speech (ADS), IDS is characterized by exaggerated prosodic features, including higher pitch and wider pitch range, as well as a slower speaking rate and simpler language (Genovese et al., 2019; Saint Georges et al., 2013; Soderstrom, 2007). These characteristics are thought to enhance infants' attention and facilitate language learning, as reflected in newborns' consistent preference for IDS over ADS (Cooper & Aslin, 1990; Fernald, 1985; Pegg et al., 1992). Importantly, IDS is not a fixed form of communication but a dynamic and adaptive system that changes with infants' developmental stage and emerging communicative abilities (Henning et al., 2005; Genovese et al., 2020). These changes occur across lexical, syntactic, and prosodic levels and serve multiple functions, including regulating attention, supporting emotional bonding, and scaffolding early language development (Saint-Georges et al., 2013; Spinelli et al., 2022). Recent research indicates that IDS may vary in populations with atypical developmental trajectories, such as preterm infants or children with genetic conditions, suggesting that caregiver speech is sensitive to infant-specific characteristics and developmental needs (Suttora & Salerni, 2011; Zampini et al., 2023; Provera et al., 2025). However, the characteristics of IDS directed at infants with visual impairment (VI) remain relatively underexplored. The present thesis therefore examines IDS directed at infants with VI compared to typically developing infants, focusing on differences in IDS prosody and their associations with infant emotionality and maternal sensitivity during the Face-to-Face Still-Face paradigm (Tronick et al, 1978).

Chapter 1 - Infant-Directed Speech

1.1. The Characteristics of Infant-Directed Speech

IDS refer to a distinct linguistic register employed by adults and caregivers when communicating with infants and young children. Compared with ADS, IDS exhibits specific linguistic characteristics and serves different functional and pragmatic purposes. These characteristics can be observed across several linguistic domains, including lexical, syntactic and prosodic features, which together are thought to support infants' attention, communication, and language development (Saint Georges et al., 2013).

1.1.2. Lexical Features

The lexical profile of IDS is marked by lexical redundancy and a more limited vocabulary compared to ADS. Early research show that mothers tend to use a small set of words with frequent repetition (Snow, 1972), a pattern that is now considered a key feature of IDS (Fernald, 1993; Laing, 2016; Tal et al., 2024). This redundancy is more common when speaking to younger infants and decreases as infants get older (Tal et al., 2024). Interestingly, experimental evidence suggests that these repetitive patterns are meaningful for infants: 6-month-old infants show a preference for repeated IDS utterances over the same utterances presented without repetition, whereas 4-month-old infants do not show this preference, suggesting developmental differences in sensitivity to IDS features (McRoberts et al., 2009).

Although IDS involves a limited vocabulary, longitudinal research point out that it is not simplistic but instead reflects a constrained yet meaningful lexical register, as reflected in longitudinal changes in maternal speech across the first year of life. Specifically, the overall maternal lexicon increases during the first half of the first year and decreases in the second half, demonstrating a quadratic trend (Genovese et al., 2020). Typical features of this register in IDS include onomatopoeia, nonsense sounds, and diminutives. Onomatopoeic words imitate real-world sounds, such as animal noises, and in IDS they are produced with higher pitch, longer duration, greater frequency, and are more often presented in isolation than conventional words (Laing et al., 2016). These features are thought to be especially salient for infants, given their still-developing linguistic capacities (Laing et al., 2016; Laing, 2019). Diminutives, or words with altered endings (e.g., doggie), occur frequently in IDS and are suggested to have prosodic properties that facilitate word segmentation across languages (Kempe et al., 2007; Kempe et al., 2012). Diminutives are more often used during an infant's first six months, which support the idea of an emotion centered speech (Genovese et al., 2020). This is in agreement with early research on IDS as an affective speech register specifically in the first months of life (Kitamura, C., & Burnham, D, 2003). Diminutive use shows a linear decline between 6 and 9 months, as IDS becomes less emotional and more pragmatic, and maternal communication becomes more functional (Genovese et al, 2020). As infants grow older, maternal speech gradually begins to resemble ADS more closely. Differences are already emerging between 1 and 3 months of age, with an increase in verbosity, lexical diversity and utterance length (Henning et al 2005), reflecting ongoing adaptation of caregiver input to infants' developing communicative and cognitive abilities (Suttora & Salerni, 2011; Genovese et al., 2020; Saint-Georges et al., 2013).

1.1.3. Syntactic Features

The syntactic features of IDS reflect the way adults speak to infants, typically producing shorter and simpler utterances compared to ADS (Saint-Georges et al., 2013). Despite this difference, IDS remains grammatically complete and well-formed, supporting the view that it is simplified but not simplistic, retaining structural coherence and occasionally including more complex elements (Genovese et al., 2019).

At the earliest stages of infancy, mothers adapt their speech to the infant's developmental level. Measurements of maternal utterances at 1 and 3 months reveal developmental changes in speech quantity and lexical characteristics, with lower lexical diversity at 1 month and a lexically richer speech by 3 months (Henning et al., 2005). Specifically, Henning et al. (2005) found that maternal utterances directed to 3-month-old infants were longer than those addressed to 1-month-old infants, suggesting developmental adaptation during the early preverbal period. Similarly, Bornstein et al. (1992) reported that mothers spoke more to older infants (13 months) than to younger infants (5 months), demonstrating age-related increases in speech quantity across infancy. One common measure of syntactic complexity is the Mean Length of Utterance (MLU), which represents the average number of morphemes or words per utterance (Brown, 1973). Studies using MLU consistently report lower values in IDS compared to ADS, indicating shorter and structurally simplified utterances (Phillips, 1973; Soderstrom, 2007; Genovese et al., 2020). Notably, MLU seems to follow a U-shaped trajectory where the trend in complexity decreases between 3 and 9 months, followed by an increase until the 12-month mark (Genovese et al., 2020). This pattern is thought to reflect simplified input during the preverbal stage and increased syntactic complexity as infants begin to babble, entering the verbal stage of development (Genovese et al., 2020; Suttora & Salerni, 2011; Saint-Georges et al., 2013).

1.1.4. Prosodic Features

Infant-Directed Speech exhibits a distinctive prosodic profile, reflected in specific acoustic characteristics that differentiate it from ADS. IDS is typically marked by higher pitch, greater pitch variation, vowel lengthening, slower tempo, and longer pauses between utterances (Fernald et al., 1989; McRoberts & Best, 1997; Soderstrom, 2007). These prosodic features create a melodically exaggerated speech pattern that infants prefer and that is thought to enhance perceptual salience (Fernald & Kuhl, 1987; Saint-Georges et al., 2013). There is broad agreement in the literature that one of the most consistently reported acoustic features of IDS is an elevated mean fundamental frequency (F0), which reflects perceived pitch and other prosodic exaggerations characteristic of IDS (Saint-Georges et al., 2013; Fernald & Simon, 1984).

As reviewed by Cristia (2013), spectrographic comparisons between IDS and ADS show that IDS typically exhibits higher overall pitch (F0), greater pitch modulation and simpler pitch contours. Elevated pitch has also been linked to attentional and emotional processes, as well as to early linguistic development in infants (Saint-Georges et al., 2013; Trainor et al., 2000; Kuhl et al., 1997), suggesting that pitch plays a key role in how infants process IDS. This heightened pitch may also reflect increased emotional expression in IDS. However, Trainor et al. (2000) argue that IDS is not uniquely distinguished by prosody alone, but rather by the greater and more freely expressed emotional content directed toward infants compared to typical ADS, underscoring the role of both acoustic and affective factors in IDS.

More recent research demonstrates that prosodic features of IDS, particularly pitch range and word rate, vary according to communicative context, with storytelling eliciting a wider pitch range and faster word rate than other tasks, demonstrating how prosodic modulation could support expressive and attentional functions (DiStefano et al., 2024). Importantly, these prosodic modifications have been observed across diverse cultural contexts, consistent with the proposal that IDS prosody reflects functionally adaptive and potentially universal communicative strategies (Broesch & Bryant, 2015). These context-dependent variations can be further understood in relation to more basic temporal features of IDS. Speech rate, often measured as the mean number of syllables produced per second, is typically slower in IDS compared to ADS, and IDS is also characterized by longer pauses and greater pitch modulation (Fernald & Simon, 1984; Narayan & McDermott, 2016), features thought to increase the salience of speech for infants (Fernald & Kuhl, 1987; Saint-Georges et al., 2013).

Considering the rhythmic profile of IDS, prosodic stress refers to the rhythmic pattern generated by stressed syllables in continuous speech. In infant-directed speech, this stress-based rhythm is often exaggerated, producing enhanced low-frequency amplitude modulations. Acoustic analyses show that IDS displays a dominance of low-frequency amplitude modulations corresponding to the prosodic stress rhythm, in contrast to ADS (Leong et al., 2014).

1.1.5. Pragmatic and Functional Features

The distinct characteristics of Infant-Directed Speech (IDS) are believed to include pragmatic and functional features, reflecting its role as a highly interactive speech register used to sustain social interaction with infants, regulate and engage their attention, and facilitate emotional connection between caregiver and child (Luksaneeyanawin et al., 1998). As discussed above, IDS changes as infants grow older and is gradually adapted to the child's developmental stage. This adaptation applies not only to linguistic features but also to its pragmatic and functional aspects, supporting social interaction with infants at different stages of their physical, emotional, and cognitive development (Luksaneeyanawin et al., 1998; Saint-Georges et al., 2013).

During the earliest stages of infancy, IDS primarily functions to support co-regulation between caregiver and infant (Spinelli et al., 2022). Maternal speech has been shown to influence non-nutritive sucking behavior in preterm infants, with sucking rates increasing relative to baseline and varying as a function of maternal voice quality, particularly pitch modulation (Butler et al, 2014), demonstrating an immediate physiological and regulatory effect of vocal features on infant behavior. Emotional expression is also particularly prevalent during this stage, and caregivers use features such as hyper-articulated vowels, which are believed to serve affective functions (Saint-Georges et al., 2013). As infants grow and their communicative and language abilities begin to develop, IDS gradually becomes more informative, descriptive, and linguistically complex (Spinelli et al., 2022). During this developmental transition, infants become increasingly socially responsive to maternal speech between 1 and 3 months, as shown by increases in gazing, smiling, and positive vocalizations, reflecting the influence of IDS on early caregiver-infant interactions (Henning et al., 2005). By around 5 months, infants begin to form social preferences for individuals who use IDS over ADS, consistent with IDS not only capturing infants' attention and engaging their emotions but also guiding their social interactions (Adena & Hannon, 2011).

The 9-month mark is a pivotal point in IDS. Around this age, IDS shows a decline in mean F0 and some affective features, alongside an increase in pitch range and the incidence of direct utterances, reflecting cognitive and perceptual development (Kitamura & Burnham, 2003). Infants begin to babble, and IDS becomes increasingly interactional, facilitating communicative exchanges. As the first-year progresses, complexity in IDS continues to increase, becoming more informational by 12 months (Genovese et al., 2020). Approaching the second year of life, infants do not show a preference for speech that has the lexical repetition and shorter utterances typical of IDS; however, they still seem to show a preference for speech with the prosodic properties of IDS. This demonstrates the important pragmatic role of the prosodic features of IDS in attracting and regulating attention, while also pointing to their potential communicative function during caregiver-infant interaction (Saint-Georges et al., 2013).

1.2. The Role of Infant-Directed Speech in Supporting Infant Development

1.2.1. Linguistic Development

IDS has been linked to a range of pragmatic, affective, and linguistic developmental outcomes. Early research primarily focused on IDS's role in linguistic development, examining its specific features and infants' immediate linguistic preferences (Snow, 1972; Phillips, 1973; Fernald, 1985), While this work have investigated how infants respond to IDS, more recent research has investigated how the characteristics of maternal IDS influence children's language development over time. Longitudinal findings indicate that the lexical and acoustic properties of maternal speech during early interactions with 6- to 12-month-old infants are positively associated with children's language abilities at age 5 (Liu, 2014). Moreover, pitch and prosodic features of IDS also seem to contribute to later vocabulary growth. For example, Han et al. (2023) found that the extent of prosodic modification mothers used when introducing unfamiliar words correlated with children's vocabulary development between 18 and 24 months, providing evidence for long-term effects of IDS on infant linguistic development. The effect of IDS during the formative period of infancy may also facilitate infant learning. Infants are better able to discriminate between words and part words after exposure to IDS compared to ADS suggesting successful segmentation of IDS but not ADS (Thiessen, 2005).

Importantly, IDS dynamically changes as infants develop. Henning et al. (2005) found that maternal speech increased in quantity and lexical diversity between 1 and 3 months, paralleling infants' growing social engagement and demonstrating how caregivers adapt their linguistic input to infants' developing communicative abilities. This dynamic adaptation highlights the role of IDS as part of a broader interactive system through which language development occurs.

Language develops through continuous interactions between caregiver and child (Liu, 2014), and early findings suggest that vocabulary development is shaped by both the child and the environment, with frequent and rich language input directly supporting faster and earlier vocabulary growth (Huttenlocher, 1991). Within this interactive framework, both the input directed to the child and the child's ability to process that input is believed to influence language acquisition. For example, infants' ability to segment speech at 7.5 months, as well as the repetitiveness of maternal speech, independently predict vocabulary outcomes at two years of age. Infants who demonstrate stronger word segmentation skills and those who are exposed to more repetitive speech tend to develop larger vocabularies, suggesting that both early processing abilities and the quality of linguistic input play a role in language development (Newman et al., 2015).

1.2.2. Cognitive Development

Infants' preference for the exaggerated prosodic features of IDS has been widely documented, and these features are thought to serve key functions related to attention and affect (Spinelli et al., 2022). Meta-analytic findings demonstrate that prototypical prosodic features of IDS are related to positive infant outcomes. Specifically, IDS prosody has been found to be associated with increased infant attention and better pre-linguistic and linguistic skills (Spinelli et al., 2017), which is consistent with the idea that the specific exaggerated characteristics of IDS serve attentional functions (Fernald, 1993). From a broader developmental perspective, IDS is also understood as part of a caregiver-infant regulatory system that supports both emotional and attentional regulation during early interaction (Papoušek & Papoušek, 1992; Saint-Georges et al., 2013 Due to the salient features of IDS, infants are better able to attend to speech and detect regularities in the speech signal. This is what Nencheva and Lew-Williams (2022) call “attention moments,” which are believed to support infants' developing understanding of speech and communication over time.

Beyond its role in attention, IDS also supports cognitive development by helping infants regulate their arousal and emotional state, with caregivers using IDS to engage and maintain infant attention while also expressing affect (Stern, Spieker, & MacKain, 1982). As noted previously, IDS contributes to the regulation of infants’ emotional states and the maintenance of attention during caregiver-infant interactions (Saint-Georges et al., 2013; Spinelli et al., 2017). From a broader developmental perspective, these regulatory functions help create conditions that facilitate infants’ processing of speech and learning from social input, highlighting the role of early regulation in cognitive development. Thus, IDS appears to support infants’ attentional and emotional regulation capacities, as well as the development of more efficient learning environments over time.

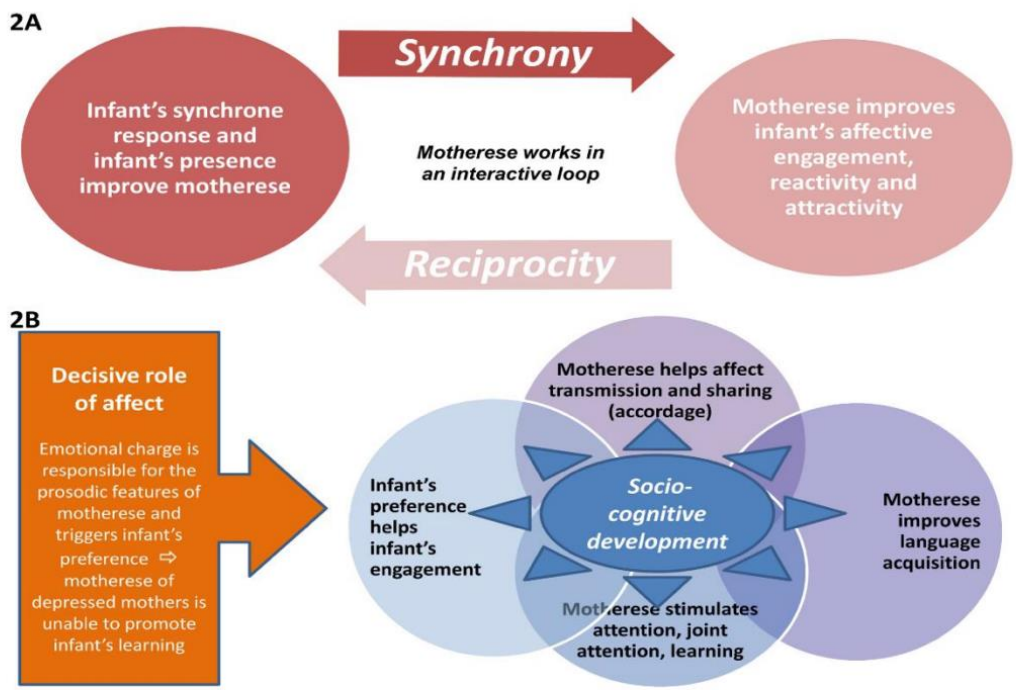
1.2.3. Social Development

In the earliest months of life, IDS functions primarily as an affective speech register (Kitamura & Burnham, 2003), with pitch playing a central part in this modulation (Fernald, 1989. Prosodic exaggeration in IDS is closely linked to emotional expression, and research suggests that IDS is more emotionally expressive than ADS, which tends to be more affectively neutral or restrained (Trainor et al., 2000; Fernald, 1989). These early social and affective functions are thought to support bonding processes and the development of interactional coordination in caregiver-infant exchanges (Papoušek, 2007).

Over time, IDS-related interactional experiences contribute to patterns of infant attentional and social engagement within dyadic communication, which are considered important components of early developmental trajectories (Saint-Georges et al., 2013). Although evidence on longer-term socio-emotional outcomes remains limited and requires further longitudinal investigation, meta-analytic findings indicate that more prototypical IDS prosody is associated with increased positive infant affect, such as smiling and vocal responsiveness, as well as greater emotional engagement during caregiver-infant interaction (Spinelli, Fasolo, & Mesman, 2017), framing IDS as a contributing factor to the emotional quality of early interactions.

Figure 1

Summary of the motherese interactive loop (2A) and its socio-cognitive implications (2B) (adapted from Saint-Georges et al., 2013)



1.3. IDS in Atypical Populations

1.3.1. Premature Birth

While much of the literature on Infant-Directed Speech focuses on typically developing infants, recent research has begun to investigate how IDS may differ in atypical developmental populations. One population that has received particular attention is preterm infants, although evidence regarding IDS in this group remains mixed. Salerni et al. (2007) reported no differences in the interactive patterns of preterm (PT) and full-term (FT) mother-infant dyads. This finding is further supported by a longitudinal study examining maternal lexical and syntactic complexity across 6, 12, 18, and 24 months, which found that maternal input directed to preterm infants during the first two years of life does not significantly differ from that addressed to full-term infants (Suttora & Salerni, 2011). However, the same study also suggests qualitative differences in how IDS is attuned to infant development. In FT infants, IDS is typically attuned to the child's linguistic development (e.g. babbling, vocalization and communicative skills), whereas in PT infants this attunement is weaker and maternal speech is influenced more in terms of the infants' motor skills and development, with maternal speech more strongly shaped by motor rather than communicative development (Suttora & Salerni, 2011).

Further evidence suggests that differences might emerge in specific linguistic features of maternal speech. In a study with 18-month-old toddlers, maternal speech directed to FT and PT children was compared in terms of lexical diversity, syntactic complexity, and overall verbosity. This study found group differences in word types and MLU, where mothers of FT children apply more lexically varied and syntactically complex utterances compared to mothers of PT children (Provera et al., 2025), demonstrating how IDS may differ in response to atypical developmental trajectories.

The relevance of these differences is underscored by the higher risk of neonatal complications and later developmental difficulties in preterm infants (Saigal & Doyle, 2008; Bhutta et al., 2002; Leone et al., 2008). Because of this, preterm infants, especially very preterm infants, often spend time in the Neonatal Intensive Care Unit (NICU), which can be recognized as a stressful postpartum period. (Pineda et al., 2023; Flacking et al., 2016; Weber & Harrison, 2019). Within this context, maternal and paternal IDS show effects on PT infants behavioral state in the NICU, inducing more alertness, more awake states, and more organized behaviors in the infant. This is consistent with what we previously know about the salient effect of IDS but reiterates the importance of familiar stimuli in a stressful environment such as the NICU (Saliba et al., 2020).

Extending this evidence, research has also examined how maternal vocalizations are dynamically modulated in response to infants' behavioral states in the NICU. In a study with 20 mother-infant dyads, mothers were asked to speak and sing to their medically stable infants in incubators. Vocal samples were extracted during periods when infants displayed specific behavioral cues, namely eye opening and smiling. Acoustic analyses showed that IDS and singing differed depending on infants' behavioral state, with greater variability, higher mean pitch, and increased sound pressure level observed when infants displayed behavioral cues (Filippa et al., 2019), demonstrating how maternal vocalizations are modulated in response to infant behavior and are closely linked to the affective qualities of IDS. This supports the idea that early vocal interaction in the NICU is dynamic and bidirectional, and that even in medically complex environments, maternal IDS remains adaptive and emotionally responsive, while also being shaped by the specific constraints and cues of preterm infant behavior.

1.3.2. Down Syndrome

Beyond PT infants, other atypical developmental conditions, such as chromosomal trisomies, have also been associated with differences in caregiver-infant interaction and IDS. A trisomy is a chromosomal abnormality in which an individual has three copies of a chromosome instead of the typical two. Trisomies can be further classified into autosomal trisomies (e.g. Down syndrome, Trisomy 18, Trisomy 13) and sex chromosome trisomies (SCT) (e.g. Klinefelter syndrome (XXY), XYY syndrome, and Triple X syndrome) (Pandel & Verma, 2021; Antonarkis, et al., 2021; Tartaglia et al., 2020).

Within Down syndrome (DS), differences in caregiver-infant interaction have been documented. In a study of children with DS (chronological age approximately 3 years, developmental age approximately 1.8 years), maternal and paternal speech was compared between children with DS and typically developing (TD) peers. Compared to parents of TD children, parents of children with DS used more affect-salient speech, including more direct statements, asked fewer questions, and referred less often to the environment while focusing more on the child's actions. However, both groups used similar levels of information-salient speech and made comparable references to children's internal states and to themselves (Falco et al., 2011), indicating that IDS in DS is selectively adapted, with a stronger emphasis on emotional rather than informational content.

Research on gaze and affect in infants with DS comes from studies examining infant-directed singing. Both DS and TD infants showed high levels of sustained gaze with their mothers during infant-directed singing. However, infants with DS demonstrated significantly lower levels of intermittent gaze compared to TD infants, suggesting a delay or deficit in attention shifting, which is hypothesized to affect infant self-regulation (de l'Etoile, 2015; de l'Etoile, 2006; Shenfield et al., 2003).

Additional evidence comes from acoustic analyses of maternal vocalizations in infant-directed singing, comparing acoustic parameters and perceived warmth in two types of infant-directed songs, a lullaby and a play song. Perceived warmth was defined as the degree to which maternal singing was observed as emotionally engaging and affectionate. Although no differences were found in singing frequency, mothers of infants with DS used a higher maximum pitch, more key changes during play songs, and took longer to establish a rhythmic structure compared to mothers of TD infants. Interestingly, mothers of TD infants were rated as singing with higher perceived warmth (de l'Etoile et al., 2017). These acoustic differences are especially interesting given that higher pitch has previously been linked to increased salience and attentional engagement in infants (Fernald & Kuhl, 1987; Fernald, 1992; Trainor et al., 2000), indicating that maternal singing to infants with DS may be adapted to their distinctive attentional and emotional needs, potentially creating a more supportive interactional environment consistent with models of intuitive parenting and dyadic interaction (Papoušek & Papoušek, 1992; Stern et al., 1982).

1.3.3. Sex Chromosome Trisomies

Sex chromosome trisomies (SCT) represent another form of genetic aneuploidy characterized by the presence of an additional sex chromosome alongside a typical karyotype (Skuse, 2018). The neuropsychological profile associated with sex chromosome trisomies (SCT) is often characterized by delays or deficits in linguistic development (Zampini et al, 2023; Tartaglia et al, 2020). Analysis of the prosodic characteristics of maternal input addressed to 8-month-old infants with SCT showed a less marked and less modulated intonation and melodic profile compared to input addressed to TD infants, indicating that IDS to SCT infants is less exaggerated (Provera, 2022). This may potentially reduce the salience and emotional register of IDS, which is thought to play a supportive role in infant development (Spinelli et al., 2017; Saint-Georges et al., 2013).

Overall, the evidence reviewed above indicates that IDS is not only shaped by typical developmental milestones but is also modulated by atypical developmental trajectories. Across populations including PT infants, DS, and SCT, IDS appears to be systematically adapted to infant-specific behavioral, cognitive, and emotional profiles, suggesting that IDS is not a static form of speech but a dynamic and flexible register that changes in response to infant cues and developmental progress.

1.4. Neural Processing of Infant-Directed Speech

1.4.1. Attention

With advances in neuroscience, IDS is increasingly investigated using neurophysiological measures such as electroencephalography (EEG), extending behavioral findings that infants preferentially attend to IDS over ADS (Cooper & Aslin, 1990; Fernald, 1985; Pegg, Werker, & McLeod, 1992). Adding neural measures to behavioral findings helps reveal how IDS is encoded during early perceptual and attentional development.

Both newborn and older infant studies provide evidence that IDS engages attentional and processing resources more strongly than ADS. For instance, Haden et al. (2020) found that in newborns, ADS elicited a centro-parietal positivity in the 200-600 ms window, whereas IDS elicited frontal negativity in the 700-900 ms window. Frontal negativity is an established marker of attentional engagement, reflecting the salient effect of IDS (Courchesne et al., 1981; de Haan & Nelson, 1997; Richards, 2003). Similarly, in 9-month-old infants, IDS varying in affective content (e.g. love, comfort, surprise, fear) was associated with increased frontal EEG power as emotional intensity increased, with fear eliciting the strongest response, alongside heart rate deceleration across affective conditions indicating sustained autonomic engagement with IDS (Santesso et al., 2007). These neural and autonomic responses illustrate how IDS engages multiple mechanisms involved in attention and the processing of salient social stimuli (de Haan & Nelson, 1997; Richards, 2003; Santesso et al., 2007).

Further evidence for early attentional sensitivity to IDS comes from studies examining infants' neural responses to acoustic properties of maternal speech and singing. In a high-density EEG study, infants were exposed to maternal ADS, IDS, and infant-directed singing. Infants were able to distinguish ADS from IDS and showed sensitivity to speech production rate and variability in speech rate. IDS elicited increased activity in right temporal regions linked to language processing, while infant-directed singing elicited activity in right frontal regions linked to emotional regulation (Dehaene-Lambertz et al., 2002; Dawson, 1994; Dawson et al., 1992; Kjeldsen et al., 2024). These responses indicate early neural sensitivity to IDS and related affective cues from birth, with processing influenced by emotional content of speech (Saint-Georges et al., 2013; Santesso et al., 2007).

1.4.2. Speech Processing, Neural Tracking and Learning

As mentioned previously, IDS has been proposed to facilitate word segmentation in infants, which may contribute to the detection of statistical regularities in speech (Thiessen et al., 2010). This has been investigated using event-related potentials (ERPs) to examine how exaggerated pitch, a defining feature of IDS, influences neural responses in a statistical learning paradigm in newborns. Findings demonstrate that neural responses are modulated by both speech register and the statistical structure of the input. Specifically, IDS elicited larger neural responses than ADS, suggesting enhanced early auditory processing. Additionally, across both speech registers, syllables with higher transitional probabilities elicited stronger neural responses, indicating sensitivity to statistical regularities, which may reflect IDS-related facilitation of both low-level auditory encoding and higher-order extraction of statistical structure in speech, with potential implications for early language learning (Bosseler et al., 2016). Similarly, Menn et al. (2022) reported higher speech-brain coherence for IDS compared to ADS at the prosodic stress rate in 9-month-old infants, while no differences are observed at the syllabic rate, proposing a selective sensitivity to prosodic structure in IDS**,** with potential implications for infants' speech processing and early language development**.**

Functional near-infrared spectroscopy (fNIRS) has also been used to examine neural responses to IDS in word learning contexts. Toddlers show increased responses to IDS in the left dorsolateral prefrontal cortex, linked to attention and cognitive control (Knight, Smith & Ellison, 2020; Kane & Engle, 2002; Brosan & Wiegand, 2017), particularly when IDS includes larger pitch exaggeration. In contrast, the inferior frontal gyrus and the temporal cortex, both parts of the traditional language network, show greater responses to ADS than IDS (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002). These findings align with the attentional role of IDS, although language-related regions appear more responsive to ADS (Zhou et al, 2022).

From functional neuroimaging research with Japanese caregivers, neural substrates underlying IDS processing have also been identified. The right caudate nucleus (RCN) has been shown to reflect experience-dependent changes in the interaction between language and emotion during IDS processing. This region appears sensitive to prosodic and lexical features of IDS, highlighting IDS as a flexible, goal-directed behavior in social communication and supporting previous findings on its developmental role (Matsuda et al., 2014).

Overall, these neurophysiological findings allow for a more comprehensive understanding of IDS processing and how its distinct prosodic and acoustic features engage distributed neural networks supporting early infant development.

Chapter 2 - Visual Impairments in Infants

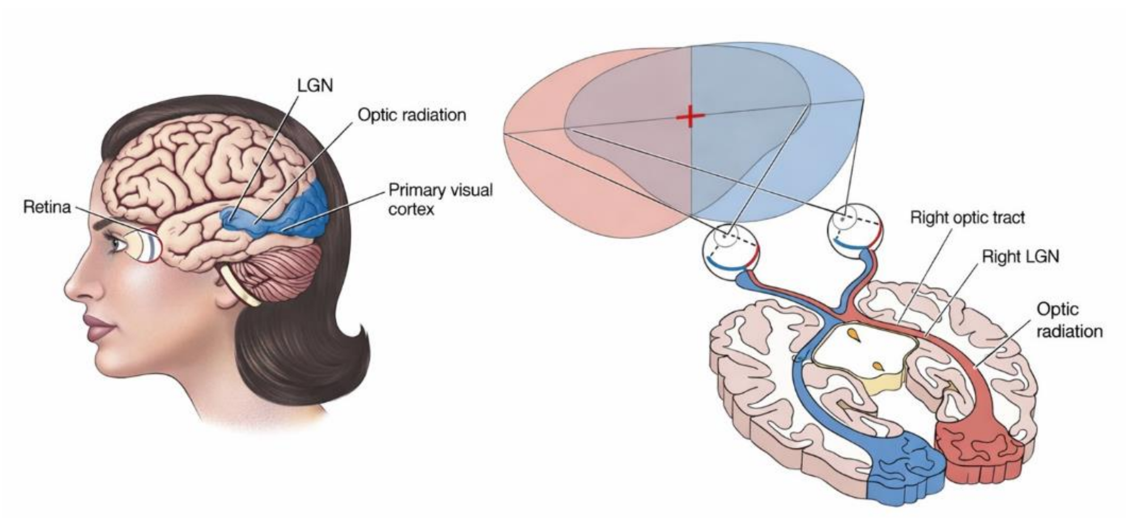
2.1. The Visual System

Vision is considered the dominant sense in humans, and the visual system occupies more than one-third of the cerebral cortex, representing a substantial part of the brain (Kandel et al., 2013). However, the system is not fully developed at birth. It continues to mature during the first months of life and is further refined throughout the early years of development (Ionta, 2021; Siu & Murphy, 2018). Due to its complexity, the development of the visual system is a prolonged process.

Vision allows us to perceive the external world by detecting the interaction between light and objects (Purves et al., 2018; Kandel et al., 2021). Light enters the eye through the pupil and reaches the retina at the back of the eye. The retina is part of the central nervous system, and the processing of visual information begins here (Purves et al., 2018; Kandel et al., 2021). The conversion of light energy into neural activity occurs in the retina, which is composed of photoreceptors, bipolar cells, and ganglion cells (Bear et al., 2020). Photoreceptors respond to light by changing their membrane potential, which influences bipolar cells that then transmit information to ganglion cells. Ganglion cells are the only retinal cells capable of generating action potentials, and their axons form the optic nerve, which carries signals to the base of the brain (Bear et al., 2020). Light is also processed through an indirect pathway involving horizontal and amacrine cells, which influence the activity of bipolar and ganglion cells. While ganglion cells can detect differences in brightness and color, more detailed visual processing occurs in higher-order brain regions. Visual information is processed through parallel pathways before reaching the visual cortex, where more complex information is interpreted (Kandel et al., 2021; Purves et al., 2018).

Figure 2

The Visual System and Parallel Pathways (adapted from Wolters Kluwer, 2016)



2.2. Visual Impairment

2.2.1. Prevalence

Vision is often measured through visual acuity, typically by using a chart to assess how sharp vision is at a distance. Normal vision is defined as 6/6 (meters) or 20/20 (feet), meaning a person can see at 6 meters (or 20 feet) what a person with normal visual acuity can also see at that distance (American Academy of Ophthalmology, 2022). According to the World Health Organization (2019), approximately 2.2 billion people worldwide have a vision impairment (VI) or blindness, representing around 27% of the global population. An estimated 1.4 million of the world's children are blind, and around 19 million are estimated to have some form of VI (Solebo, Teoh, & Rahi, 2017).

At-risk groups for VI include PT infants and infants with DS**.** These infants are at increased risk due to the vulnerability of the developing visual system, as well as reported abnormalities in ocular structures and a higher prevalence of neurological and retinal complications associated with premature birth (Diggikar, 2023; Liyanage & Barnes, 2015). In FT infants, the retina and retinal vasculature are typically fully developed at birth, however, this developmental stage is often incomplete in PT infants (Fierson, 2018). Extreme prematurity increases the risk for retinopathy of prematurity (ROP), a condition that can threaten vision, and in severe cases and cause permanent vision loss (Blencowe et al., 2013; Diggikar, 2023).

2.2.2. Classifications

VI can be categorized based on level of visual function and forms. VI are placed into visual acuity categorized: mild, moderate, severe visual impairment and blindness, ranging from mild reduction in vision to complete or near-complete loss of sight (World Health Organization, 2019), while visual forms are classified based on the location of the primary impairment. This distinction is usually made between ocular forms, where the impairment originates in the eye or optic nerve, and cerebral forms, where the impairment involves the visual pathways in the brain (Martín et al., 2016; Ospina, 2009). Ocular causes include conditions such as cataracts, macular degeneration, and glaucoma, all of which directly affect the structure of the eye and can lead to reduced vision or ocular-related blindness. By contrast, cerebral visual impairment (CVI) is used to describe VI arising from damage to the brain's visual pathways during early development, often involving not only the visual cortex but also subcortical regions, white matter tracts, and higher-order processing areas (Hoyt, 2003; Good, 2009; Martín et al., 2016). Infants with CVI may present with reduced visual acuity, visual field deficits, and impairments in complex visuospatial processing (Good et al., 2001; Fazzi et al., 2004). In addition to these two main forms, VI may also result from acquired neurological damage such as stroke or trauma, affecting structures beyond the eye, including the geniculate body, optic radiations, and visual cortical areas. These cases are often classified as neurological VI and can result in profound impairment (Good, 2007).

The two main forms of VI, ocular and cerebral, can be further conceptualized within a detailed functional categorical framework.
Within ocular forms (i.e., peripheral visual system disorders), two descriptive categories can be distinguished:

(i) **Peripheral visual deficits.** Peripheral visual deficits refer to alterations in the pre-chiasmatic visual pathway, which includes the retina, optic nerve, and ocular media (Purves et al., 2018). Symptoms of peripheral visual deficits include reduced visual acuity, reduced overall visual behavior, nystagmus, and strabismus. Conditions such as retinopathy of prematurity (ROP), a retinal vascular disorder affecting preterm infants, also fall within this category (Hartnett, 2010; American Academy of Ophthalmology, 2022).

(ii) **Pathologies of the oculomotor system.** Pathologies of the oculomotor system refer to disorders affecting the part of the visual system that controls eye movement and position. Structures involved include the cranial nerves, the extraocular muscles, and brain regions responsible for eye movement control, particularly the cerebellum. These pathologies result in symptoms affecting coordinated eye movements, including diplopia (double vision), nystagmus (involuntary eye movements), strabismus (ocular misalignment), and impaired gaze control or difficulty tracking moving objects (Kandel et al., 2021; Rucker, 2007; Strupp et al., 2011).

Within cerebral forms (central visual system), two descriptive categories can be distinguished:

(iii) **Visual deficits of central origin.** Visual deficits of central origin are cortical deficits, caused by damage to, or malfunctioning of the retrogeniculate visual pathways, including optic radiations, occipital cortex, visual associative areas (Fazzi et al., 2012, Dutton & Jacobsen 2001, Good et al., 2001). These visual deficits may cause reduced visual acuity, abnormalities in the perception of color, and gaze-gesture-posture coordination disorders (Fazzi et al., 2012).

(iv) **Disorders related to the malfunctioning of visual associative systems.** Disorders related to dysfunction of visual associative systems. The associative visual systems include the occipito-temporal and occipito-parietal streams, which represent the two main pathways of visual processing. The occipito-temporal system (the "what" pathway) is specialized in object identification and visual recognition and is critical for the perception and recognition of objects. In contrast, the occipito-parietal system (the "where/how" pathway) is involved in the analysis of spatial location and in the processing of visual motion and visuomotor control (Mandonnet, 2009; Kandel et al., 2021). Dysfunction in these systems can result in difficulties affecting motion perception, color processing, spatial and temporal orientation, object and face recognition, and reading (Barton, 2022).

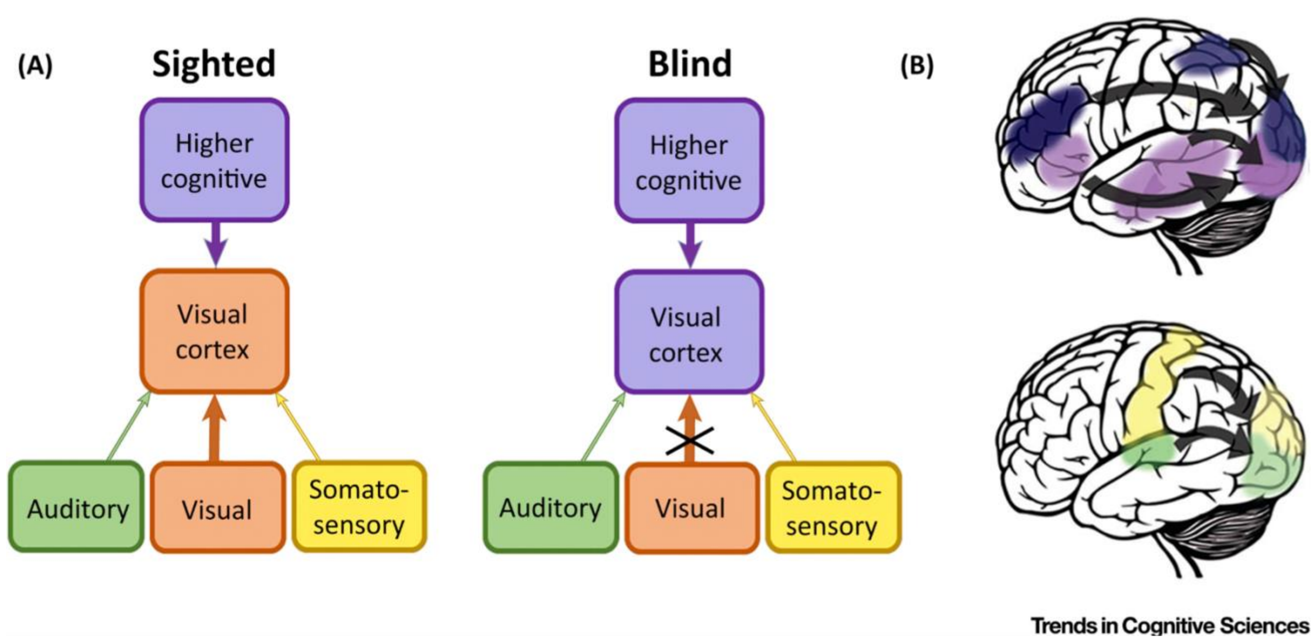
2.3. Developmental Outcomes in Visual Impairments

2.3.1. Sensory and Perceptual Development

Human perception relies on the integration of multiple sensory systems to interpret and interact with the environment. Although perception is inherently multisensory, vision often plays a dominant role in early development due to its high spatial resolution and rich informational content (Ghazanfar & Schroeder, 2006; Atkinson & Braddick, 2003). When vision is impaired from birth or early infancy, infants rely more heavily on their remaining sensory modalities, especially touch and hearing, to explore and engage with their environment (Merabet & Pascual-Leone, 2010). This adaptation is supported by crossmodal neuroplasticity, in which sensory systems being reorganized and potentially becoming more efficient following VI (Sathian & Stilla, 2010; Merabet & Pascual-Leone, 2014). For example, research on multisensory and spatial processing in infants with severe VI indicates a distinct audiotactile processing pattern, characterized by increased dependence on tactile input and differences in multisensory integration compared with typically developing infants (Gori et al., 2021), supporting the view that early VI may lead to a reorganization of sensory weighting.

Figure 3

Mechanisms of plasticity in the blind visual cortex (adapted from Bedny, 2017).



Note. This figure illustrates the shift from visual to non-visual sensory and higher-cognitive inputs to the visual cortex in blindness. Panel B depicts the segregation and recruitment of visual cortical regions for sensory and higher-cognitive functions in blind individuals

2.3.2 Motor Development

Physical milestones and locomotor skills in infants and children with visual impairment (VI) are reported differently in the literature. Some studies suggest that motor development does not differ substantially between typically developing infants and infants with VI (Hellemans et al., 2011), while others report delayed gross motor development across most developmental milestones in this population (Celeste, 2002). Greater differences are observed in cases of profound VI, particularly in infants and children with blindness (Hellemans et al., 2011). Similar patterns are also observed in older children, with blind children performing significantly worse than their sighted peers across all assessed locomotor and object-control skills (Wagner et al., 2013). Overall, severity of VI appears to be a significant factor influencing motor performance across domains (Prechtl et al., 2001; Haibach et al., 2014).

Longitudinal evidence from Adelson and Fraiberg (1974), who observed gross motor development in 10 blind infants from birth to 2 years of age, reported a typical pattern of development among the infants, although this differed from sighted infants, particularly after the first year. Delays in self-initiated mobility were evident from early developmental stages, suggesting that vision plays a central role in the achievement of mobility. Once blind infants became proficient in reaching toward sound, they began to creep and walk, gradually mapping the concrete world around them, highlighting the reliance on auditory cues in infants with VI.

Using video analysis of young children with VI, Murphy & O'Driscoll (1989) reported delayed and atypical motor development patterns, particularly in balance, coordination, and sequencing of movement, and argued that motor development is not only delayed but also qualitatively different. Similarly, Tröster & Brambring (1993) observed that blind infants show delays in their ability to control posture and stabilize balance in sitting and standing during the first year of life. Delays were particularly evident in skills that involve self-initiated changes of posture or position, such as sitting up or standing, as also reported by Murphy & O'Driscoll (1989). Findings further suggest that blind infants may, to some extent, catch up with sighted infants in the development of static postural control by the end of the first year; however, in dynamic postural skills, such as moving into sitting or standing positions, delays seem to be more pronounced and longer lasting. Additionally, specific motor milestones such as reach-to-grasp behavior also seems to be affected. In particular, the "pick-up" phase of grasping objects, including hand shaping and object acquisition, appears delayed in infants with congenital VI. However, the reaching component itself is found to follow a relatively typical developmental trajectory (Petri et al., 2025).

2.3.3. Cognitive Development

Cognitive development encompasses areas such as attention, memory, learning and mentalizing abilities. In line with motor development findings, children with profound visual impairment are at much greater cognitive developmental risk than children with some remaining vision (Sonksen & Dale, 2002). This reflects the idea of experience-dependent development, which is particularly vulnerable in infants and children with profound visual loss. Vision contributes to cognition through experiential learning and interaction with the environment, providing critical input for early learning through exploration and engagement. As a result, VI may reduce opportunities for learning, which in turn may slow cognitive development. Even small amounts of residual vision appear to have a protective effect on cognitive development (Dale & Sonksen, 2002).

Within the domain of attention, Tadić and colleges (2010) suggested that VI affects' components of attention, particularly establishing attention with an adult, maintaining attention during interaction and shifting attention between objects. Their findings indicated that children with profound VI show greater difficulty with attention shifting, while children with some residual vision perform closer to sighted children (Tadić, Pring, & Dale, 2009). This is also applied to sensorimotor cognitive tasks and object-learning abilities, with infants who retain some functional vision showing developmental performance closer to sighted peers, whereas infants with profound VI are associated with greater delays (Dale et al., 2017).

While VI has been associated with delays in certain aspects of attention and early cognitive functioning, findings in the domain of memory present a more complex picture. Adults who were born with congenital blindness show auditory-verbal short-term memory advantages for verbal material, including improved performance on verbal recall tasks, with better recall of letters and digits in correct serial order on forward, backward, and complex span tasks (Arcos et al., 2022a; Arcos et al., 2022b). Comparable findings have been reported in children, where comparisons between congenitally blind and sighted children reveal better performance in verbal short-term memory tasks (e.g., remembering digits and word-like material in order) in blind children, but no differences in working memory (Swanson & Luxenberg, 2009). Later research did however find group differences also in working memory (Withagen et al., 2013), but it is important to note that this discrepancy may reflect differences in the cognitive tasks used. It is not completely clear why blind children and adults show a general advantage in memory tasks, but a plausible explanation might be related to greater reliance on sequential processing in blind individuals, which is heavily used in memory tasks (Raz et al., 2007; Sepúlveda et al., 2024). It is also possible that crossmodal neuroplasticity may be a contributing factor to these differences, through reorganization of sensory cortices and increased recruitment of auditory and tactile systems for cognitive processing (Merabet & Pascual-Leone, 2010; Sathian & Stilla, 2010), which may enhance the efficiency of encoding and maintaining sequential information (Bedny, 2017; Raz et al., 2007).

Beyond attention and memory, researchers have also examined the impact of VI on social-cognitive development. Mentalizing, or Theory of Mind, refers to the ability to understand mental states such as emotions, beliefs, intentions, and desires in oneself and others, and to use this understanding to interpret and predict behavior (Premack & Woodruff, 1978; Wellman, 1992). In a study of school-aged children with congenital VI, findings indicated no clear delay in Theory of Mind when assessed using verbally based tasks; however, these children may still experience early difficulties in pragmatic aspects of everyday communication, particularly in naturalistic social interaction (Pijnacker, Vervloed, & Steenbergen, 2012). **Nevertheless**, it has been suggested that children with VI who pass Theory of Mind tasks show higher verbal IQ and verbal mental age than those who fail (Green et al., 2004; Minter, Hobson, & Bishop, 1998).

2.3.4. Language Development

Language development is a lifelong process, although sensitivity to language input is most prominent in the early years of life, a period often referred to as a “critical period”. During this heightened sensitivity period, variations in sensory experiences may impact linguistic development (Kuhl, 2004; Werker & Hensch, 2015). In the context of VI, differences in developmental trajectories include expressive language and verbal comprehension. Findings indicate that infants with severe VI and residual vision tend to follow relatively typical developmental trajectories, whereas those with profound VI are at greater risk of delay, deceleration, and developmental instability over time (Dale & Sonksen, 2002), consistent with findings reported in previously discussed domains.

Children with profound VI and blindness seem to follow a distinct but systematic pathway of language development. They tend to acquire temporal concepts before spatial ones, demonstrate difficulties in pragmatics and perspective-taking, and show a strong reliance on adaptive communication strategies. These differences are thought to be partly mediated by variations in caregiver-child interaction patterns (Andersen, Dunlea, & Kekelis, 1993). Meta-analytic evidence further suggests that pragmatic language difficulties are more prevalent in individuals with VI across development (Cheng et al., 2023). Even when verbal intelligence and structural language abilities are intact, children with congenital VI show an increased risk of socio-communicative difficulties (Tadić et al, 2010).

Although the severity of VI indicates an effect on language development, social interaction seems to play an important role in speech learning and verbal comprehension (Kuhl, 2004; Sakkalou et al., 2018). Maternal sensitivity at 8-17 months has been linked to improvements in verbal comprehension and greater gains in understanding language later in life. This early sensitivity shows a long-term positive association with advances in verbal comprehension from infancy to around three years of age (Sakkalou et al., 2018). These findings highlight the role of early social interaction in shaping language development, suggesting a close link between linguistic and broader social-communicative development.

2.3.5 Social and Communicative Development

Infants are active participants in their environment, learning through continuous sensory input (Hyvärinen et al., 2014). Vision plays a central role in early development by supporting social orienting, joint attention, and interpersonal engagement. When visual development is disrupted, the typical pathways for early social interaction are altered, which may influence the development of communication and social understanding during critical periods (Sonksen & Dale, 2002; Gori et al., 2021). Eye-tracking evidence supports the importance of early visual engagement in this process, showing that greater attention to the mother's eyes at 6 months is associated with better social abilities at 18 months, suggesting that early visual attention may help scaffold later social development (Wagner et al., 2013).

The impact of VI in infancy on social-communicative development is not uniform across individuals. As in other developmental domains, outcomes vary depending on the severity of impairment, neural development, and environmental support, with more severe impairment generally associated with greater risk of atypical developmental trajectories (Sonksen & Dale, 2002). Given the central role of vision in supporting early social interaction, differences are particularly evident in the social domain. Infants with VI may experience reduced opportunities for spontaneous joint attention and visually guided social learning, which can influence later communication and social engagement (Salley et al., 2016; Wagner et al., 2015; Grumi et al., 2021). A recent report also highlights that children with early-onset severe VI may experience delays across social, emotional, and communicative domains, with potential long-term consequences (World Health Organization, 2026), highlighting the importance of early interactional processes, in shaping developmental outcomes.

2.4. Impact of Visual Impairment on Early Interactions

The caregiver-infant dyad is an interactive system that can be considered to consist of two subsystems, the caregiver and the infant (Von Bertalanffy, 1968; Provenzi et al., 2018), both of which are complex and dynamic. This system is shaped by individual regulation within both the infant and the caregiver, as well as by regulatory processes within the dyad.

Much of the literature on caregiver-infant interactions focus on sighted children, as vision plays a key role in early interaction. Newborns show sensitivity to caregiver facial features within the first days of life (Goren et al., 1975; Bushnell, 2001), and infants are able to discriminate their mother's face from that of a stranger in behavioural tasks (Field et al., 1984; Bushnell, Sai & Mullin, 1989; Pascalis et al., 1995), as well as show a preference for looking at their mother's face compared to unfamiliar faces (Brooks-Gunn & Lewis, 1981; Pascalis & de Schonen, 1994), highlighting the importance of vision in early social interaction.

Within this context, caregiver-infant interactions are important for early development, supporting infants' cognitive, emotional, and communicative abilities, with early sensitive interactions identified as predictors of later cognitive and socio-emotional development in children (DiCorcia & Tronick, 2011; Henning & Striano, 2011; Provenzi et al., 2018). Early theories emphasized the effects of VI in caregiver-infant interactions (Fraiberg, 1977), as much of early social exchange within the dyad is visually mediated, including eye contact, reciprocal smiling, and the observation of facial expressions (Bishop, 1998). However, findings show that this dyadic interaction is bidirectional and develops its own organized pattern over time, shaped by both caregiver behavior and infant characteristics (Green et al., 1980).

Despite early concerns, later videotaped studies demonstrate that blind infants can engage in typical patterns of early communication and are active participants in dyadic interaction (Urwin, 1978, 1983; Rowland, 1984; Als et al., 1980), which has been further supported by Preisler (1990), who found that both blind and visually impaired infants are active participants in early dyadic interaction, although greater challenges are observed in cases of more severe impairment. Importantly, VI does not prevent the development of organized interactional patterns when caregiving is supportive, with the dyad forming a highly responsive interactional system (Als et al., 1980).

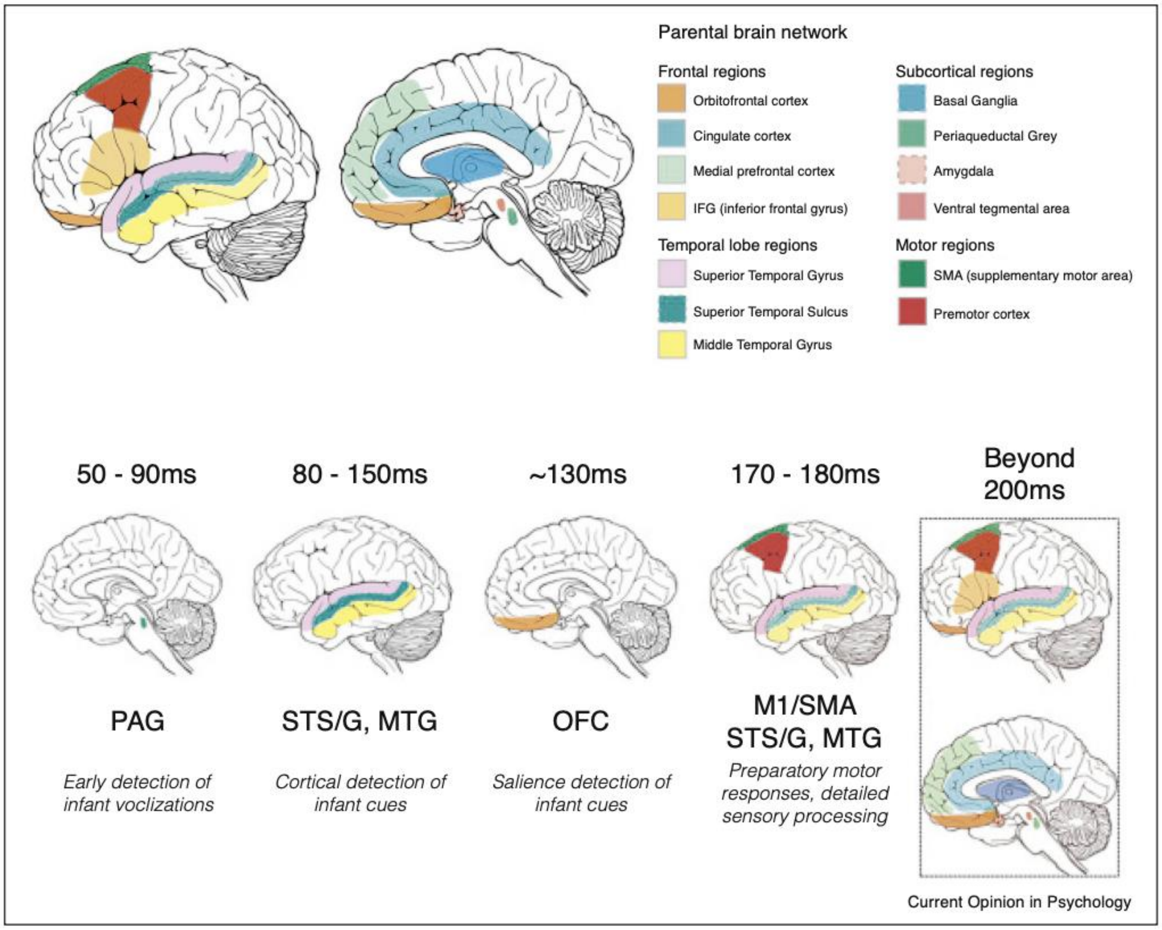
A recent review examining interactions between visually impaired children and their parents reports that these interactions involve different structures and timing than interactions with sighted children, resulting in altered patterns of infant social engagement and increased parental directiveness. However, these interactions are adaptive, bidirectional, and also rely on non-visual sensory channels (Grumi et al., 2021), and do not appear to prevent harmonious caregiver-infant interactions (Chiesa et al., 2015). At the same time, parenting an infant with VI may present additional challenges. A study investigating parental stress, anxiety, and depression in mothers of visually impaired infants found that mothers of 1-year-old infants with VI showed increased risk for parenting stress, with higher levels of stress associated with greater risk of adult anxiety and depression (Sakkalou et al., 2017), reflecting the complex nature of caregiver-infant interactions in VI.

To capture these interactional dynamics, the Face-to-Face Still-Face (FFSF) paradigm (Tronick et al., 1978) is a well-validated and widely used procedure for assessing early socio-emotional regulation in infants across the first year of life. It has provided insight into infants’ capacity to regulate socio-emotional states, a process considered a cornerstone of later affective, social, and cognitive development and resilience (Aghaziarati & Nejatifar, 2023; Ekas et al., 2018). More broadly, early emotion regulation emerges through a dynamic interplay between biologically based predispositions and neurophysiological processes that support adaptive responses to environmental stress (Campagna et al., 2021; Ekas et al., 2018), and is shaped by caregiver behavior, particularly sensitivity and responsiveness (De Wolff & van IJzendoorn, 1997).

At the neurobiological level, this adaptive capacity is supported by a distributed parental brain network involving subcortical salience systems, the orbitofrontal cortex, temporal social-perceptual regions and motor preparation areas, which together facilitate rapid, pre-conscious responses to infant cues (Parsons et al., 2017). This distributed system reflects a caregiver-infant dynamic that adapts regulatory processes within the dyad, consistent with developmental models of bi-directional and context-sensitive co-regulation (Provenzi et al., 2018). Overall, within this framework, VI does not disrupt the caregiver-infant system in a linear manner, but instead reshapes interactional processes within a dynamic, bidirectional system.

Figure 4

Parental brain network illustrating the neurological correlates of intuitive parenting, including subcortical, cortical, and motor systems (adapted from Parsons et al., 2017).



2.5. Infant-Directed Speech in Early Visual Impairment

Communicative interactions between caregivers and infants have long been considered central to the development of social and emotional functioning (Trevarthen, 1984; Stern, 1993). During caregiver-infant interactions, IDS is a key communicative tool used by caregivers and undergoes dynamic changes during the first year of life, reflecting caregivers' ability to adapt their speech to infant development (Rowe, 2012).

In the context of VI, IDS may play a particularly important role, as infants with VI process sensory information differently during interaction with their caregivers. Reduced access to visual social cues leads to a greater reliance on auditory information for social engagement and attention regulation (McConachie, 1990; Grumi et al., 2024; Chiesa et al., 2015). As mentioned in Chapter 1, IDS is modulated by atypical developmental trajectories, and factors such as maternal sensitivity, caregiver emotional state, and socioeconomic status have been examined in relation to IDS.

Caring for an infant with atypical developmental needs may affect caregivers across emotional, cognitive, and interactional domains, potentially influencing speech patterns as well as caregiver responsiveness and sensitivity (Singer et al., 1996; McConachie, 1990; Chiesa et al., 2015; Saint-Georges et al., 2013). The existing literature highlights the importance of caregiver-infant interaction and the role of IDS in early socio-emotional development; however, a significant gap remains in understanding how IDS is specifically characterized in infants with visual impairment.

Chapter 3 - The Current Study

3.1. Aims

The present study investigates IDS prosody in mother-infant dyads with and without VI, and its associations with infant emotionality and maternal sensitivity during a structured social stress context (the Face-to-Face Still-Face procedure). The primary aim is to examine group differences in IDS prosodic features and their associations with infant emotional regulation and maternal sensitivity across dyads with and without VI.

RQ1: Do mothers of infants with VI differ from mothers of sighted infants in IDS prosodic features?

RQ2: How are maternal IDS prosodic features associated with infant emotionality and maternal sensitivity across groups?

Based on previous research linking the prosodic characteristics of IDS to infant socioemotional functioning, it was hypothesized that maternal IDS prosodic features would be associated with both infant emotionality and maternal sensitivity. Given the limited literature examining these associations in the context of VI, the direction of these relationships was explored rather than explicitly predicted.

3.2. Methods

3.2.1 Study Design

This study adopted a cross-sectional observational design. Mother-infant dyads were assessed during a single laboratory visit using the Face-to-Face Still-Face (FFSF) paradigm. All measures were collected within the same session. Maternal and infant behavior were recorded and analyzed alongside maternal speech during the interaction.

3.2.1. Participants

Mother-infant dyads were recruited from the Developmental Neuro-Ophthalmology Unit of the IRCCS Mondino Foundation (Pavia). A total of 46 mother-infant dyads participated in the study, comprising 25 infants with VI and 21 sighted infants (control group). The groups were matched for infant age and sex. Sighted infants had no history of visual, sensory, neurological, or medical conditions and were born at term following uncomplicated pregnancies. Infants in the VI group were included if they had received a clinical diagnosis of low vision based on the Teller Acuity Cards and did not meet the criteria for complete blindness. VI was classified as peripheral visual impairment (PVI), cerebral visual impairment (CVI), or ocular motor impairment (OMI), provided that all conditions resulted in reduced grating acuity. PVI involved pathology affecting the eye or optic nerve, CVI reflected impairment of the retro-geniculostriate visual pathways and/or associated cortical areas, and OMI comprised abnormalities of ocular motility (e.g., nystagmus or oculomotor apraxia) that reduced grating acuity. Families of infants with VI were recruited through the Developmental Neuro-Ophthalmology Unit, and sighted infants were recruited from the same geographical region.

3.2.2. Procedure

After providing written informed consent, mother-infant dyads participated in the Face-to-Face Still-Face (FFSF) paradigm (Tronick et al., 1978). Infants were seated in a highchair directly facing their mothers, with a distance of approximately 40 cm between them. The FFSF paradigm consisted of three episodes: (1) a 2-minute face-to-face play interaction (Play), (2) a 2-minute maternal still-face episode (Still-Face), and (3) a final 2-minute face-to-face play interaction (Reunion). Prior to the procedure, mothers were instructed to interact with their infants during the Play and Reunion episodes as they would at home. During the Still-Face episode, mothers were instructed to stop interacting, maintain a neutral facial expression, and continue to look at their infant. Mothers received audio cues indicating the onset of each episode.

3.2.2.1. Recording procedure. During the FFSF procedure, two cameras were used to record the procedure: one focused on the infant's head and body, while the other captured the mother's head and upper body.

3.2.2.2. Behavioral coding procedures. Videos from the two cameras were edited offline to produce a single video with simultaneous frontal view of the mother and infant. Videos were micro-analytically coded using the Noldus - The Observer XT software.

3.2.3. Measures

3.2.3.1. Infant-directed speech. Maternal verbal input (i.e., maternal verbal production) during the first minute of the Still-Face Procedure was analyzed using PRAAT speech analysis software (Boersma & Weenink, 2005), with a pitch range set between 100-750 Hz. A vocal production was defined as a sound with vocalic content, separated from the subsequent vocalization by a silent interval longer than 0.3 s (Stern et al., 1977). Prosodic measures extracted for analysis included mean fundamental frequency (F0), F0 range, maximum F0, and minimum F0.

3.2.3.2. Infant emotionality. Infant emotionality was coded into three mutually exclusive categories: (1) positive emotion, (2) neutral emotion, and (3) negative emotion (Provenzi et al., 2017). Positive emotionality was coded when infants displayed clear positive affect, expressed through facial expressions (e.g., mouth and eye activity, facial movements) and/or vocalizations (e.g., laughter). Negative emotionality was coded when infants displayed clear negative affect, expressed through facial expressions and/or nonverbal behaviors such as crying, fussiness, signs of distress, or vocal protest. Neutral emotionality was coded when the infant did not display clear positive or negative emotionality through facial expression or other modalities (e.g., the infant is calm, relaxed). See Appendix A for description of the behavioral variables of interest.

3.2.3.3. Maternal sensitivity. Maternal sensitivity was assessed during video-recorded mother-infant interactions using the Sensitivity Cut from the Global Rating Scales of Mother-Infant Interaction (GRS; Gunning, Fiori-Cowley, & Murray, 1996). This standardized observational coding system provides global ratings of maternal behavior across eight dimensions, including warmth, responsiveness, acceptance, behavioral and verbal intrusiveness, closeness, following, and turn-taking during interaction. Following the authors' guidelines, three scores were derived: sensitivity, intrusiveness, and remoteness. Each score was rated on a 5-point scale ranging from 1 to 5. See Appendix B for detailed descriptions of the coding scheme.

3.2.4. Data Analysis

Firstly, a series of independent samples t-tests and Pearson's chi-square tests were conducted to assess baseline differences between the two groups (control group and VI group) in relation to available sociodemographic characteristics of mothers and infants. More specifically, the groups were compared with respect to infant age at the time of the experiment, corrected infant age (for preterm infants), and gender.

The main aim of the study was to examine group differences in IDS acoustic measures (F0 mean, maximum, minimum, and range), maternal sensitivity (GRS dimensions including warm, responsive, accepting, following, non-intrusive behavior and speech, close contact, and turn-taking), and infant emotionality measures (positive, neutral, and negative emotional expressions). Independent samples t-tests were used to compare continuous variables between groups, while chi-square tests were used to examine group differences in categorical variables.

Pearson's correlation analyses were then conducted to explore associations between IDS features, maternal sensitivity (GRS), and infant emotionality variables across the full sample.

All analyses were conducted using Jamovi software (version 2.3.28; The Jamovi Project, 2022). A significance threshold of $p < .05$ was used. Visualizations were generated using Python (version 3.13).

3.3. Results

3.3.1. Samples characteristics

Sample characteristics are reported in Table 1. The final sample comprised 46 mother-infant dyads, including 21 sighted infants (45.7%) and 25 in infants with VI (54.3%). The sample was predominantly male (71.7%), with females accounting for 28.3%. No significant group differences were found in infant age at the time of the experiment, corrected age, or gender distribution.

Table 1

Sample Characteristics

	Control *M(SD)*	Visual Impairment *M(SD)*	χ^2	*p*
Age	11.1 (1.06)	11.8 (1.88)	-1.53	.13
Corrected Age	11.1 (1.06)	11.3 (1.49)	0.49	.48
Sex			0.49	.48
Male	14	19		
Female	7	6		

Note. Values represent means (M) and standard deviations (SD). Control = typically developing dyads; Visual Impairment = dyads with infant visual impairment.

3.3.2. Infant-Directed Speech

No significant group differences were found between the two groups for any of the prosodic measures. However, descriptive trends were observed across all prosodic features, with the VI group demonstrating consistently higher scores than the control group. Specifically, mothers in the VI group showed higher mean fundamental frequency (F0), higher maximum and minimum F0 values, and a wider pitch compared to the control group. The descriptive statistics for all prosodic measures are presented in Table 2 and visualized in Figure 5.

Table 2

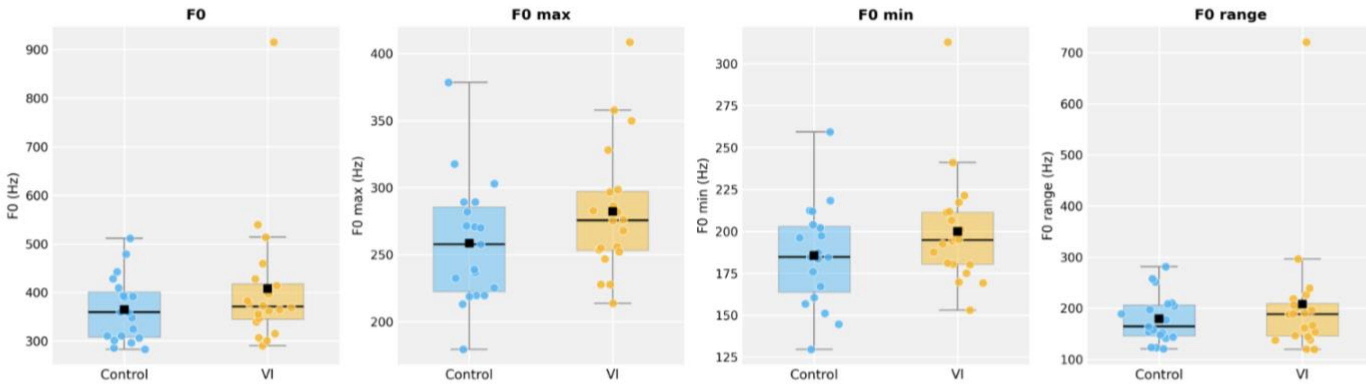
Infant-Directed Speech Characteristics

	Control *M(SD)*	Visual Impairment *M(SD)*	*t*	*p*
F0	364 (67.2)	407 (136)	-1.23	.22
F0 max	258 (46.1)	282 (48.2)	-1.55	.12
F0 min	185 (30.4)	199 (33.7)	-1.37	.17
F0 range	179 (47.2)	207 (128)	-0.91	.36

Note. Values are presented as means (M) and standard deviations (SD). Control group = typically developing dyads; Visual impairment group = dyads with infant visual impairment.

Figure 5

Group Differences in Infant-Directed Speech Prosody



3.3.3. Infant emotionality across Still-Face episodes

Results of independent-samples t-tests examining infant emotionality during the Still-Face Procedure are presented in Table 3. During the Play episode, infants in the VI group displayed higher levels of neutral emotionality whereas sighted infants displayed higher levels of positive emotionality. These group differences are illustrated in Figure 6. No significant group differences were found for negative, neutral, or positive emotionality (all *p*s > .05) during the Still-Face and Reunion episodes.

Overall, these results suggest that group differences in infant emotionality were present only during the initial Play interaction, with infants in the VI group showing more neutral and less positive emotionality compared to sighted infants.

Table 3

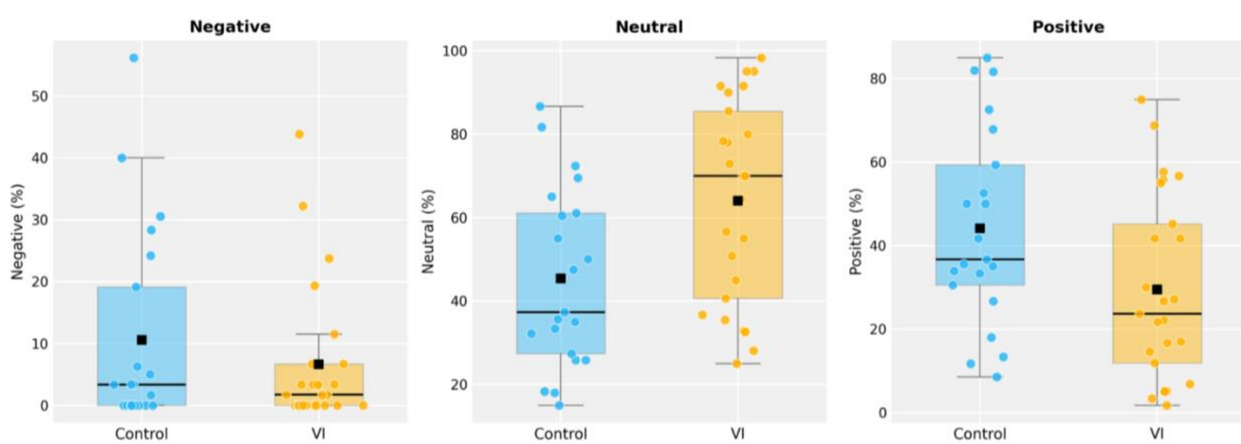
Infant Emotionality Across All Episodes of the Still-Face Procedure

Episode	Variable	Control *M(SD)*	Visual Impairment *M(SD)*	*t*	*p*
Play	Negative	10.5 (16.1)	6.62 (11.3)	0.96	.34
	Neutral	45.3 (21.6)	63.9 (24.2)	-2.71	.01
	Positive	44.0 (23.5)	29.4 (22.1)	2.17	.03
	Negative	43.7 (32.9)	42.0 (31.2)	0.18	.85
Still	Neutral	50.2 (29.5)	51.3 (27.9)	-0.12	.89
	Positive	6.00 (6.90)	6.66 (10.1)	-0.25	.80
	Negative	28.5 (28.6)	25.2 (33.8)	0.35	.72
Reunion	Neutral	45.8 (25.1)	53.1 (29.7)	-0.88	.38
	Positive	25.5 (19.4)	21.6 (20.3)	0.66	.50

Note. Values are presented as means (M) and standard deviations (SD). Control group = typically developing dyads; visual impairment group = dyads with infant visual impairment. Statistical significance was set at $p < .05$.

Figure 6

Group Differences in Infant Emotionality During the Play Episode



3.3.4. Maternal Sensitivity Group Differences

Results of independent-samples t-tests examining maternal sensitivity are presented in Table 4. A significant group difference was observed for turn-taking, with control group mothers showing higher levels of turn-taking compared to mothers in the VI group. In addition, there was a non-significant trend for warmth, with control group mothers scoring higher than mothers in the VI group. No significant group differences were found for the remaining dimensions of maternal behavior (all ps > .05).

Overall, these findings suggest that maternal sensitivity was largely comparable between groups across most dimensions, apart from turn-taking, where control group mothers demonstrated greater interactive synchrony during the Still-Face Procedure.

Table 4

Maternal Sensitivity During Still Face Procedure

	Control *M(SD)*	Visual Impairment *M(SD)*	*t*	*p*
Warm	4.19 (0.60)	3.84 (0.62)	1.92	.06
Responsive	4.38 (0.80)	4.16 (1.06)	0.78	.44
Accepting	4.48 (0.81)	4.24 (0.83)	0.97	.33
Following	3.33 (1.01)	3.20 (0.95)	0.45	.65
Non-intrusive behavior	4.76 (0.43)	4.60 (0.70)	0.91	.36
Non-intrusive speech	4.95 (0.21)	4.96 (0.20)	-0.12	.90
Close	5.00 (0.00)	4.96 (0.20)	0.91	.36
Turn taking	4.95 (0.21)	4.56 (0.82)	2.12	.03

Note. Values are presented as means (M) and standard deviations (SD). Control group = typically developing dyads; visual impairment group = dyads with infant visual impairment. Statistical significance was set at $p < .05$.

3.3.5. Correlational Analyses in the Control Group

3.3.5.1. Associations between emotionality and prosody. Several significant relationships were found between emotional expressions and acoustic features of infant-directed speech (Pearson's correlations, r; significance set at $p < .05$; Table 5). Higher infant negative emotionality during the Play episode was associated with greater negative emotionality during the Still and lower neutral emotionality during the Still episode. Negative and neutral emotionality during the Still episode were strongly negatively correlated, indicating that infants who displayed more negative emotionality tended to display less neutral emotionality.

Maternal prosodic features were also linked to infant emotionality. Higher maternal maximum pitch (F0 max) related to greater infant negative emotionality during both the Play and Still (r = episodes, and to lower neutral emotionality during the Still episode. Similarly, higher maternal minimum pitch (F0 min) related to greater infant negative emotionality during both the Play episodes, and to lower neutral emotionality during the Still episode.

Table 5

Pearson Correlations Between Infant Emotionality and Maternal Prosodic Features

	Play negative affect	Still negative emotions	Still neutral emotion	F0 max	F0 min
Play negative emotions	-				
Still negative emotions	.545*	-			
Still neutral emotion	-.526*	- .982***	-		
F0 max	.561*	.467*	-.482*	-	
F0 min	.567*	.554*	-.582**	.943***	-

Note. $p < .05$, $p < .01$, $p < .001$. All correlations are Pearson correlations (r).

3.3.5.2. Prosody and maternal sensitivity. Maternal prosodic features were strongly intercorrelated, with higher overall F0 associated with higher maximum and minimum pitch values, and F0 max and F0 min also showing a strong positive association.

Maternal prosody was associated with maternal sensitivity behaviors. Higher overall F0 and higher F0 max were positively associated with greater maternal warmth (see Figure 7)**.** In contrast, higher F0 and F0 max were negatively associated with non-intrusive behavior and turn-taking behavior (see Figure 8). Associations involving F0 min were weaker and did not reach statistical significance. Non-intrusive behavior and turn-taking were highly correlated, indicating a very strong association between these variables.

Table 6

Correlations Between Prosodic Measures and Maternal Sensitivity Behaviors in the Control Group

	F0	F0 max	F0 min	Warm	Non-intrusive speech	Turn taking
F0	-					
F0 max	0.909***	-				
F0 min	0.786***	0.943***	-			
Warm	0.502*	0.503*	0.428	-		
Non-intrusive speech	-0.527*	-0.629**	-0.586**	-0.308	-	
Turn taking	-0.527*	-0.629**	-0.586**	-0.308	1.000**	-

Note. * p < .05, ** p < .01, *** p < .001. All correlations are Pearson correlations (r).

Figure 7

Correlation Between Maximum Fundamental Frequency (F0 Max) and Warmth in the Control Group

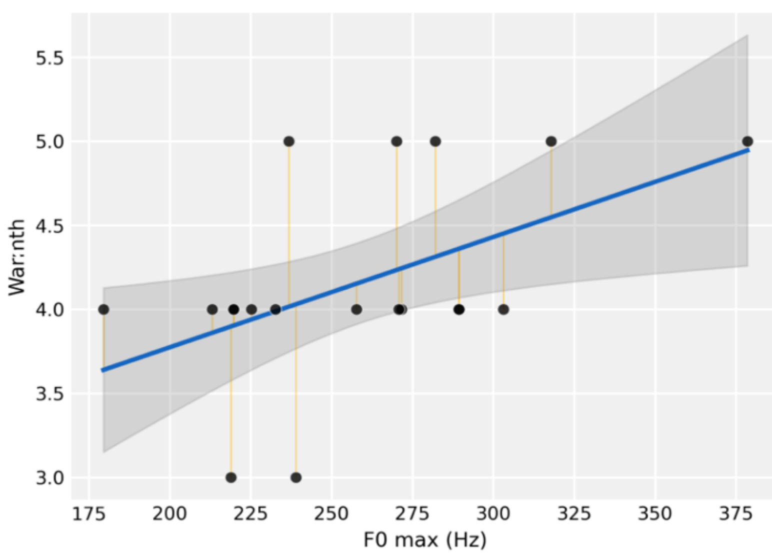
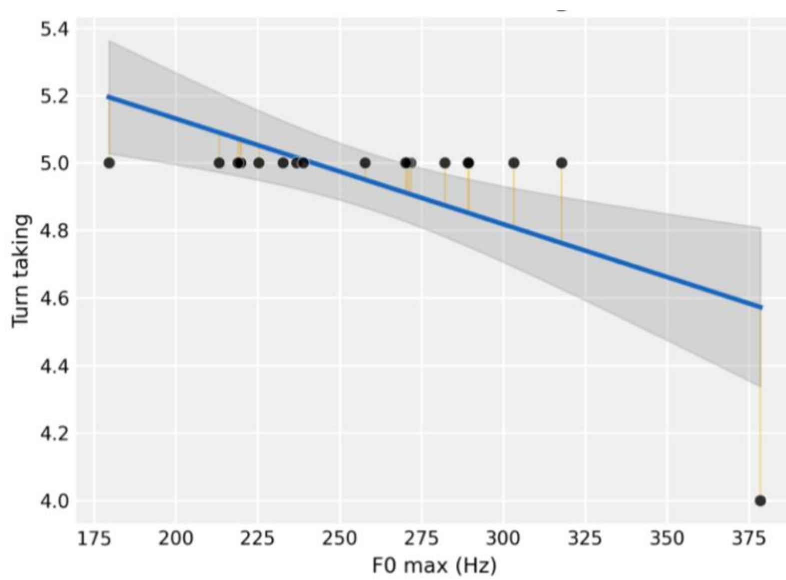


Figure 8

Correlation Between Maximum Fundamental Frequency (F0 Max) and Turn-Taking in the Control Group.



3.3.6. Correlations in the Visual Impairment Group

3.3.6.1. Prosody and emotionality. Prosodic measures were strongly intercorrelated, with F0 positively associated with F0 max ($r = .86$, $p < .001$). Maternal prosody was also associated with infant emotionality. Higher maternal maximum pitch (F0 max) was associated with greater infant positive emotionality during the Still-Face episode ($r = .50$, $p = .05$; see Figure 9), while higher maternal minimum pitch (F0 min) showed a stronger positive association with infant positive emotionality ($r = .65$, $p < .01$; see Figure 10).

Figure 9

Correlation Between Maximum Fundamental Frequency (F0 Max) and Positive Emotionality During the Still-Face Episode

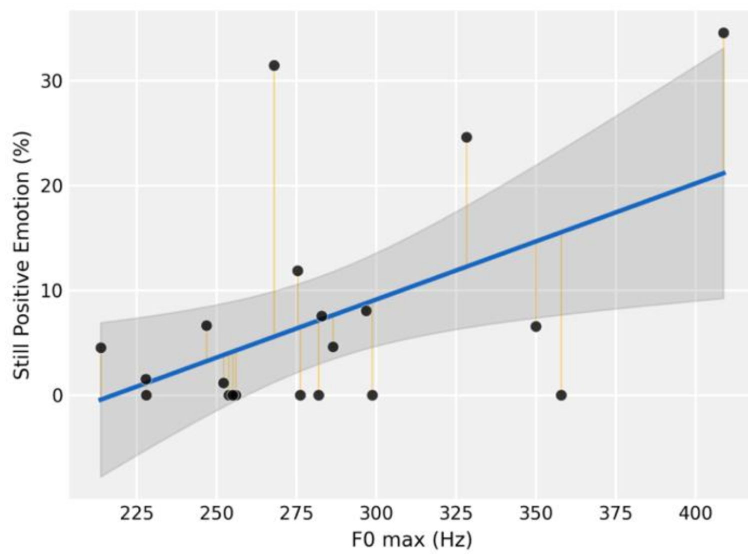
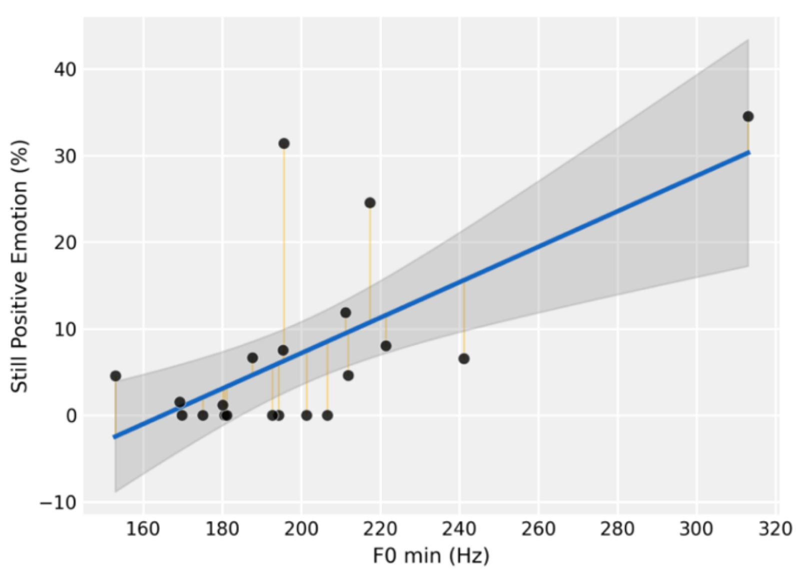


Figure 10

Correlation Between Minimum Fundamental Frequency (F0 Min) and Positive Emotionality During the Still-Face Episode

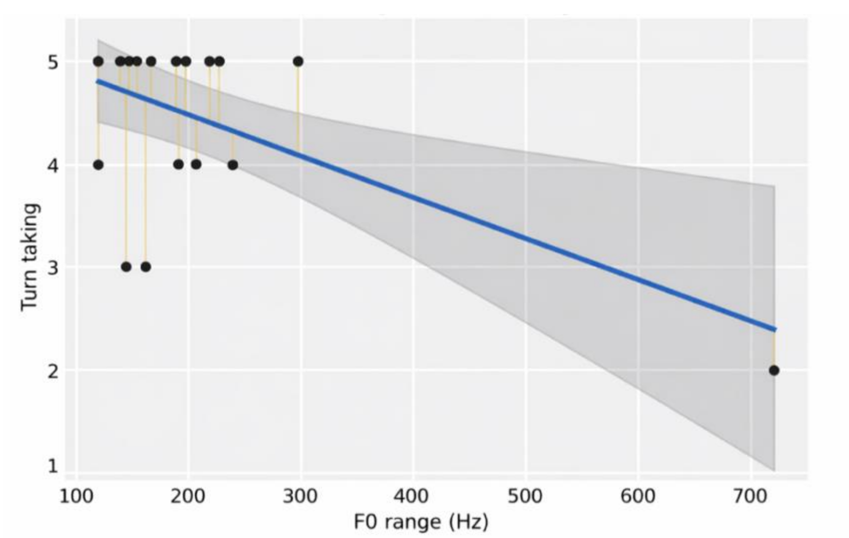


3.3.6.2. Prosody and turn-taking. Prosodic measures were strongly intercorrelated in the VI group, with higher fundamental frequency (F0) being strongly associated with a wider pitch range ($r = .96$, $p < .001$).

Maternal prosody was also associated with turn-taking behavior. Higher fundamental frequency (F0) was negatively associated with turn-taking ($r = -.548$, $p < .05$), whereas a wider pitch range was positively associated with turn-taking ($r = .574$, $p < .05$).

Figure 11

Correlation Between Mean Fundamental Frequency (F0) and Turn-Taking in the Visual Impairment Group



3.3.6.3. Positive emotionality and following. Maternal maximum pitch (F0 max) was positively associated with infant positive emotionality during the Still-Face episode ($r = .401$, $p < .05$) and with maternal following behavior ($r = .401$, $p < .05$).

3.4. Discussion

3.4.1. Group Differences and Descriptive Trends in Infant-Directed Speech Prosody

The main aim of this study was to investigate differences in IDS prosody in mother-infant dyads with and without VI. Although no significant group differences were found across prosodic features, descriptive trends were observed. Specifically, consistently higher values were found for all acoustic measures (mean fundamental frequency (F0), maximum and minimum F0, and pitch range) in the VI group. This pattern suggests a tendency toward more acoustically exaggerated infant-directed speech in mothers of infants with VI.

Exaggerated prosodic features in IDS are widely thought to serve pragmatic and affective functions and to support infant attention (Spinelli et al., 2022; Fernald, 1993). In the context of VI, the observed trends may reflect a compensatory adaptation involving reduced visual input and increased reliance on vocal modulation during caregiver-infant interaction. In turn, this could potentially facilitate emotional communication and attentional engagement by enhancing the auditory salience of maternal speech. However, given that these effects did not reach statistical significance, they should be interpreted with caution. These findings are broadly consistent with evidence that IDS is flexibly adapted to infants' developmental and communicative contexts in atypical populations (Suttora & Salerni, 2011; Spinelli et al., 2017). (Suttora & Salerni, 2011; Spinelli et al., 2017).

3.4.2. Infant-Directed Speech Prosody and Maternal Interactive Behavior

Maternal sensitivity was largely comparable between groups, with the exception of turn-taking, which was significantly lower in the VI group. Turn-taking refers to how often and how appropriately the mother responds verbally to the infant during interaction. High scores indicate timely and coordinated responses, while low scores indicate fewer or poorly timed responses, or limited verbal engagement. This significant group difference suggests that, while caregiving sensitivity is largely preserved in the VI group, reciprocity in mother-infant exchanges may be affected. This could reflect differences in the availability of visual cues that typically support the timing and fluidity of early dyadic interactions.

In the control group, higher fundamental frequency (F0) and higher maximum frequency (F0 max) were associated with greater maternal warmth, suggesting that more exaggerated prosody may reflect increased affective expressiveness during dyadic interaction. This is consistent with previous research linking prosodic exaggeration in IDS to emotional expression (Trainor et al., 2000; Fernald, 1989), which is thought to support early bonding processes and interactional coordination in caregiver-infant exchanges (Papoušek, 2007). However, all measures of maternal pitch (F0, F0 max, and F0 min) were negatively associated with both non-intrusive behavior and turn-taking, suggesting that mothers who used a more exaggerated vocal style also tended to show more intrusive interaction patterns and reduced coordination in turn-taking with their infants. Although higher pitch is a prototypical feature of IDS and serves important affective and attentional functions, excessive prosodic exaggeration may potentially disrupt the balance of interaction by limiting opportunities for reciprocal exchanges. A highly elevated vocal register may also be perceived as intrusive within the dyadic context, thereby reducing interactional coordination.

Interestingly, in the VI group, associations between prosodic measures and turn-taking appeared more differentiated. Higher fundamental frequency (F0) was associated with lower levels of turn-taking, consistent with the pattern observed in the control group, suggesting that this aspect of prosodic modulation may serve distinct communicative functions within dyadic interaction. In contrast, a wider pitch range was positively associated with turn-taking, indicating a more flexible or context-dependent use of prosodic variation to support interactional coordination in dyads with VI. These findings therefore highlight the importance of variability in prosody, rather than overall prosodic elevation, for facilitating coordinated interaction in this group.

This interpretation is supported by previous research showing that pitch range increases during the first year of life as IDS becomes more interactionally oriented, reflecting greater vocal modulation that facilitates attentional engagement and emerging communicative exchanges between caregiver and infant (Kitamura & Burnham, 2003; Saint-Georges et al., 2013).

3.4.3. Infant-Directed Speech Prosody and Infant Emotionality

In the control group, a strong negative correlation between IDS features and both negative and neutral emotionality in the Still-Face episode was observed. In relation to this, higher maternal pitch (F0 max and F0 min) was associated with greater infant negative emotionality and lower infant neutral emotionality in both the Play and Still-Face episodes, suggesting that higher pitch may be linked to increased infant emotional reactivity rather than neutral disengagement. These findings are consistent with the observed pattern in maternal behavior, suggesting that a more exaggerated prosodic profile may be associated with greater infant emotional reactivity during interaction.

In the VI group, higher maternal pitch levels (both maximum and minimum) were associated with greater infant positive emotionality during the Still-Face episode. This is in line with existing findings showing that elevated pitch is linked to attentional and emotional processes in infants

(Saint-Georges et al., 2013; Trainor et al., 2000), alongside evidence highlighting the flexibility of IDS prosody across developmental and contextual conditions (Fernald, 1993; Suttora & Salerni, 2011; Bornstein, 2012).

Importantly, maternal following behavior was associated with greater infant positive emotionality during the Still-Face episode. Maternal following reflects the extent to which the parent responds to infant initiative versus directing interaction. This finding is consistent with evidence that when mothers are more responsive to infant initiatives, infants show better emotional regulation and more positive affect even in stress-inducing situations, aligning with previous work on infant emotion regulation through contingent caregiver responses (Tronick, 1978, 1989; Feldman, 2007; Mesman et al., 2009).

3.4.4. Dyadic Regulation Within a Dynamic Systems Framework

Overall, the findings in this study revealed no significant group differences in IDS prosody, yet meaningful associations between IDS prosody, infant emotionality, and maternal behavior were observed. Within a caregiver-infant dynamic systems perspective, which conceptualizes regulation as an adaptive and reciprocal process within the dyad (von Bertalanffy, 1968; Provenzi et al., 2018), IDS can be understood not only as a group characteristic but as a functional component of this system. In line with previous research framing IDS within processes of dyadic regulation and affective synchrony in caregiver-infant interaction, IDS prosody may be embedded within broader patterns of interactional coordination between caregiver and infant.

3.4.5. Limitations and Future Directions

This exploratory study aimed to investigate IDS prosody in mother-infant dyads with and without VI, and its associations with infant emotionality and maternal behavior during a structured social stress context. Several limitations should be acknowledged.

One limitation of this study was the relatively small sample size, which reduced statistical power and generalizability. In addition, only mother–infant dyads were included, excluding fathers. Future research should therefore examine both maternal and paternal IDS, ideally within larger sample to provide a more comprehensive understanding of caregiver-infant interaction.

A further limitation concerns the cross-sectional design, which does not allow for causal inferences of the findings. Longitudinal design would be valuable to examine developmental trajectories and directionality of effects over time.

Because the current study focused exclusively on IDS prosody and did not include other relevant linguistic features of IDS, such as lexical, syntactic, and functional-pragmatic characteristics, future research should incorporate these aspects to capture additional dimensions of IDS.

Overall, this study has several limitations. Future research should aim to replicate these findings while addressing the methodological limitations outlined above.

3.5. Conclusion

This study investigated dyadic interactions between mothers and infants with VI, with a focus on IDS prosody, maternal behavior, and infant emotionality. Approximately 19 million infants and children worldwide are affected by VI, yet there is still limited understanding of how maternal speech and behavior are associated with early caregiver-infant interactional processes in this clinical population. Although no significant group differences were found in infant-directed speech (IDS) prosody, several meaningful associations emerged between maternal prosody, maternal behavior, and infant emotionality.

Early caregiver-infant interactions provide an important foundation for emotional, social, and communicative development. In infants with VI, where access to visual social cues is reduced, vocal communication may play a particularly important role in supporting dyadic regulation and interactional coordination. The findings of this study suggest that IDS should be understood within the broader context of caregiver-infant interaction, in which maternal vocal behavior, infant emotionality, and maternal responsiveness operate as interconnected components of a dyadic system.

From a clinical perspective, these findings highlight the importance of further investigating the vocal and prosodic components of early mother-infant interactions in families affected by VI. A better understanding of these interactional processes may help identify the specific needs of infants with VI and their families and inform the development of interventions and support strategies aimed at strengthening early caregiver-infant relationships.

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Appendix A

Coding Scheme for Infant Emotionality.

Variable	Code	Description
Emotional state	Positive emotionality	Display of clear positive affect, expressed through facial expressions (e.g., mouth and eye activity, facial movements) and/or vocalizations (e.g., laughter).
	Negative emotionality	Display of clear negative affect, expressed through facial expressions and/or nonverbal behaviors such as crying, fussiness, signs of distress, or vocal protest.
	Neutral emotionality	No display of clear positive or negative emotionality through facial expression or other modalities (e.g., the infant is calm, relaxed).

Appendix B

Coding Scheme for Global Rating Scales (GRS) - Sensitivity Cut. (Gunning, Fiori-Cowley, & Murray, 1996).

Dimension	Description	High Score (5)	Low Score (1)
Warm vs. Cold	Parental attitude and emotional tone toward the infant, including expressions of affection versus anger or criticism.	Parent expresses frequent positive affect. Facial expression and vocal tone convey warmth, affection, and endearment. Physical contact is supportive and nurturing (e.g., holding, caressing).	No signs of warmth or affection. Behavior may include frequent critical, negative, or emotionally cold comments.
Responsive vs. Unresponsive	Parental ability to perceive and respond appropriately to infant signals and behaviors.	Parent is highly attuned and responsive, consistently noticing and appropriately responding to both subtle and clear infant cues (facial, vocal, and behavioral).	Parent largely ignores infant signals, including clear bids for attention or interaction.
Accepting vs. Rejecting	Degree to which the parent accepts and supports the infant's behavior.	Parent does not criticize, dismiss, or override infant behavior. Follows the infant's lead and reflects the infant's affect and interests positively.	Parent frequently criticizes, ignores, dampens, or replaces infant behavior or initiatives.
Following vs. Demanding	Extent to which the parent follows the infant's lead versus imposing their own agenda.	Parent follows the infant's current state and initiates interaction in alignment with the infant's behavior or readiness.	Parent frequently makes demands or requests that are not aligned with the infant's current behavior or engagement.
Non-intrusive behavior vs. Intrusive behavior	Degree to which parental behavior supports or disrupts infant regulation and engagement.	Parent behavior is consistently non-intrusive and supports infant regulation and engagement.	Parent behavior frequently interrupts or disrupts infant engagement or regulatory state.

Non-intrusive speech vs. Intrusive speech	Degree to which parental vocalizations support or disrupt infant regulation.	Speech is appropriately timed and supportive, facilitating infant engagement without overwhelming or interrupting.	Speech is intrusive, poorly timed, or disrupts infant regulation and interaction.
Close vs. Remote	Emotional and physical availability of the parent.	Parent is consistently emotionally and physically engaged with the infant.	Parent is frequently disengaged, emotionally distant, or self-focused.
Turn-taking vs. Silent	Quality and appropriateness of parental vocal turn-taking.	Parent consistently engages in appropriate, contingent turn-taking.	Parent is frequently silent or does not engage in appropriate conversational turn-taking.

Scoring Guide

1. **Sensitivity**

Mean score of the first 5 dimensions. This score ranges from 1 (poor) to 5 (good).

2. **Intrusiveness**

Mean score of intrusive behavior and intrusive speech scores. The score will range from 1 (intrusive) to 5 (non-intrusive).

3. **Remoteness**

Mean score of remote and silent. The score will range from 1 (remote) to 5 (close).