# "IT'S NOT JUST *WHAT* WE SAY OR DO, BUT *HOW* WE SAY AND DO IT": A REVIEW OF STUDIES ON INFANT-DIRECTED MODIFICATIONS

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***Abstract:*** *Infant-directed speech (IDS) and infant-directed actions (IDA) represent specific behavioural modifications of adults when they communicate with infants and young children. Infant-directed modifications (IDMs) have specific behavioural representations marked by high positive affection, greater expressiveness, simplification, and increased repetition. Both IDS and IDA appear as part of the same larger behavioural system of IDMs. However, so far, studies have analysed the features and functions of these behaviours separately.*

*Compared to adult-directed speech, IDS is characterised by longer pauses, a slower tempo, more prosodic repetition, higher fundamental frequency, longer vowels, repetitive intonation structures, and greater melodiousness. In IDA, compared to adult-directed actions, the amplitude of movements, simplification, and number of repetitions tend to increase as the distance between communication partners decrease.*

*In this review, we draw a parallel between IDS and IDA to show that adults change both their speech and actions in similar ways and that both actions and speech change depending on the infant's age and/or developmental stage. We discuss possible (biological) mechanisms that elicit the use of IDS and IDA and argue that this specific type of adult behaviour has a unique impact on how infants perceive and process information.*

*Insights on biological, behavioural, and functional aspects of IDMs could provide a new perspective on the importance of early interactions and knowledge acquisition in both typically developing children and those with developmental disorders.*

***Keywords:*** *infant-directed speech, infant-directed actions, motionese, early development, infants*

## INTRODUCTION

When interacting with infants and young children, adults tend to modify their behaviour compared to their behaviour when communicating with other adults. These modifications include a particular way of speaking (acoustic features), linguistic adaptations, specific use of gestures, and changes in a range of other (non-verbal) behaviours, such as physical distance, hand movements, and facial expressions.

These intuitive modifications of adult behaviour may seem unusual or unnecessary, but this is by no means the case. The importance of these modifications for child development has been systematically confirmed. Such specific and specially adapted behaviours contribute to an infant's attentiveness and increased affective responsiveness (Brand & Shallcross, 2008; Fernald, 1985; Fernald & Kuhl, 1987; Kosie, 2019; Koterba & Iverson, 2009; Meyer et al, 2023; Santesso et al., 2007; Sulpizio et al, 2018; Werker & McLeod, 1989), regulation of an infant's own interaction behaviours (Papoušek et al., 1990), and establishment of emotional bonds. They also help infants understand the communicative intentions of adults (Fernald, 1989; Sirri et al., 2020) and how to take turns in conversations (Arias & Peña, 2016; Kalashnikova & Kember, 2020). Moreover, they facilitate the parsing of events

and an analysis of continuous actions, i.e., they help segment incoming stimuli into relevant units, both for speech (Kemler Nelson et al., 1989; Lee et al., 2008; Papoušek et al., 1987; Thiessen et al., 2005) and actions (Brand et al., 2002; Levine et al., 2019). Consequently, they facilitate the acquisition of language (Floccia et al., 2016; Gervain et al., 2008; Golinkoff & Alioto, 1995; Graf Estes & Hurley, 2013; Hirsh-Pasek et al., 1987), promote imitation (Elsner, 2007; Williamson & Brand, 2014), and stimulate independent research (Koterba & Iverson, 2009).

Infant-directed modifications (IDMs) might also be referred to as child-*adapted* behaviours because they are characterised by a high degree of qualitative and quantitative adaptations to the child's processing capacities, attentional characteristics, and interaction/communication skills.

However, research has rarely analysed this phenomenon in its entirety. Most studies have focused on either infant-directed speech (IDS) or infant-directed actions (IDAs). It appears that both are part of the same larger behavioural system of specific IDMs made by adults during infant-adult communication.

In this review, we attempted to unify the current knowledge on IDS and IDAs in order to examine the following topics:

(1) Historical changes in terminology of IDMs;

(2) Behavioural characteristics of IDS and IDA;

(3) Ways in which IDS and IDA change according to the age and/or developmental stage of the child;

(4) Possible mechanisms that elicit the use of IDS and IDA;

(5) Specific neurobiological responses to IDS and IDA in infants.

Taken together, all current knowledge on IDS and IDA lead to the conclusion that both IDS and IDA share many common characteristics, functions, and mechanisms and that they probably represent different behavioural manifestations of the same system of intuitive IDMs that are important for early learning in infants.

The importance of knowing the characteristics, developmental changes, and functions of IDMs lies not only in a better understanding of the basic interaction and learning processes, but also potentially in applying this knowledge to improve the quality of input and create optimal interactions with children with developmental delays/disorders. This could in turn contribute to easier understanding of communication partners, better language acquisition, higher imitation rates, and improved overall learning ability of children. Some studies have found strong evidence that IDMs are positively associated with language development in children with autism spectrum disorder (ASD) (Bottema-Beutel & Kim, 2021), late talkers (Hampson & Nelson 1993), and preterm infants (Suttora et al., 2020). However, parents of at-risk children (Zampini et al., 2020) and children with ASD (Onnis et al., 2021; Woolard et al., 2022) tend to differ in IDMs compared to parents of typically developing children. These data suggest that exposure to optimal IDMs may produce positive changes in characteristics of social interaction and learning in at-risk children and those with developmental delays/disorders.

## TERMINOLOGY

The analysis of IDMs began with the recognition of IDS. Initially, it was referred to as *baby talk* (Lukens, 1894), but later, the term *motherese* became more popular. Since this manner of speaking is not solely characteristic of mothers, the more "correct" and gender-neutral name *parentese* was proposed (e.g., Ramirez-Esparza et al., 2014). However, even this term does not truly take into account an extremely important feature – the fact that this way of speaking is used by (almost) everyone when addressing a child (e.g., IDS in fathers, Fernald, et al., 1989; grandmothers, Shute & Wheldall, 2001; and nonparents, Jacobsen et al., 1983).

Therefore, using the term IDS or child-directed speech (CDS) is clearer, even though other terms can be found in the literature (e.g., caregivers' speech, caregiver register, caregiver talk, nursery talk). An analysis of the different terms in the literature suggested that experts and research-

ers should use the term CDS (Saxton, 2008). However, the term IDS is more commonly used, probably because most research on CDS has been conducted with infants. Some studies even distinguish between these two terms (e.g., Liu et al., 2009) when comparing features of speech used with infants (IDS) and small children (CDS).

Viewing IDS in a broader context, as "part of a ritualised, multimodal, temporally organised, affiliative interaction" (Dissanayake, 2004; p. 512), led to a new phenomenon that merited exploration: IDA (also called infant-oriented parental repertoire, child-directed actions, child-directed movements, child-directed motionese, or simply *motionese*, along the lines of *motherese/parentese*). This term was defined by Rebecca Brand and her colleagues in 2002 and clearly describes changes in the organisation of movements by mothers when interacting with children in early life (Brand et al., 2002). They defined the term "action" as "any voluntary bodily movement (with or without the involvement of objects) not strictly linguistic in nature" (p. 72).

Other terms/concepts used to describe the movements parents make when communicating with infants include *gesturese* (e.g., Dimitrova & Moro, 2013), *gestural motherese* (Iverson et al., 1999), and infant/child-directed gestures (Zammit et al., 2005). We could argue that gesturese lies somewhere in between IDS and IDA. Although gestures are primarily (hand) movements used by parents in infant-directed communication and therefore resemble IDA, they are often studied as a component accompanying IDS (since gestures accompany speech), especially since they are part of the linguistic message.

There is no single, unified term that encompasses both IDS and IDA. Several different terms with similar meanings have been used in the literature. Some authors (e.g., Abu-Zhaya et al., 2016; Werker et al., 1994) use the term "infant-directed communication" as a broad term that combines all forms of behaviour that are modified when an adult interacts with an infant or young child (speech, gestures, facial expressions, touch, actions with objects, and so on) compared to interaction/communication with other adults. Schick et al. (2022) similarly used the term "child-directed communication" to refer to "all communication specifically directed at children, in which the properties and structure of the signal often change in predictable ways" (p. 2), including speech, gestures, and actions. Another broader term sometimes used is "infant/child-directed input" (Brand et al., 2007). Shneidman et al. (2014) mentioned the term "child-directed cues." Daniel Stern (1997; reprint 2002) referred to the entire constellation of parental behaviours as "infant-elicited social behaviours" and noted that "they would be considered outright bizarre if performed toward anyone but an infant (with the partial exception of a young animal or perhaps a lover)" (p. 24). Similarly, Schick et al. (2022) pointed out that adults "communicate with small children in unusual and highly conspicuous ways" (p. 1). From these observations alone, it is clear that adults tend to alter their overall communication on multiple levels in a very unique and specific way when interacting with infants.

In the present review, similar to some other authors (e.g., de Moor & Gerson, 2020; Fukuyama & Myowa-Yamakoshi, 2013; Murata et al., 2015), we will use the term "infant-directed modifications" (IDMs) to describe modifications that adults make in infant-directed communication in both speech (IDS) and actions (IDA).

## BEHAVIOURAL CHARACTERISTICS OF IDMs

From a biological perspective, it is probably important to note that IDMs are not specifically human behaviour, i.e., both IDS and IDA have been described in other species, including gorillas (Luef & Liebal, 2012), chimpanzees (Fröhlich et al., 2016), squirrel monkeys (Biben et al., 1989), free-ranging macaques (Masataka et al., 2009), bats (Fernandez & Knörnschild, 2020), and zebra finches (Chen et al., 2016).

Although only one term is used to encompass changes in vocal communication by adults, IDS includes specific modifications to two different aspects: acoustic (how the speech sounds) and structural components (content; the language used).

Compared to adult-directed speech (ADS), IDS is characterised by longer pauses, a slower tempo, more prosodic repetition, higher fundamental frequency, longer vowels, repetitive intonation structures, and greater melodiousness (Fernald, 1989; Fernald & Simon, 1984; Genovese et al., 2019; Grieser & Kuhl, 1988; Narayan & McDermott, 2016; Stern et al., 1983). Because of these features, it often sounds sonorous or song-like.

The language produced by adults is simplified and characterised by shorter sentences, less complex utterances, multiple repetitions, and a simpler vocabulary (Bernstein Ratner, 1988; Hayes & Ahrens, 1988; Kavanaugh & Jirkovsky, 1982; Phillips, 1973). For example, when addressing three-month-old children, fathers and mothers use statements that typically consist of three or fewer words, and nearly half of the statements are repetitions (Papoušek et al., 1987). IDS is also described in hearing-impaired mothers when they use sign language with their children (Masataka, 1992), and even in the prenatal period when mothers address their unborn children (Parlato-Oliveira et al., 2021), which is also referred to as fetal-directed speech.

Analysis of child-directed behaviour began with studies of IDS. However, over time, researchers have found that when adults address infants, toddlers, and preschool children, they modify not only the characteristics of speech, but also other (non-verbal) behaviours. Gogate et al. (2000) analysed how mothers coordinate IDS with object motion and touch. They found that this type of "multimodal IDS" facilitated the acquisition of new words. A task in which mothers were asked to show features of (new) objects to their infant or an adult (Brand et al., 2002) showed that the movements of the mothers differed significantly in the two situations. As predicted by the authors, presentation of objects to infants was characterised by higher levels of interactivity and enthusiasm, closer proximity to the infant, a greater range of motion, overt repetition, and simplification. Further analyses also revealed more frequent eye contact and a larger amount of interactive conversation (Brand et al., 2007), a slower pace of movement (Rohlfing et al., 2006), and a longer presentation of the effect of movement on the object (van Schaik et al., 2020). In IDA, compared to adult-directed actions (ADA), the amplitude of movements, simplification, and number of repetitions increases as the distance between communication partners decreases (Brand et al., 2002, 2007; Chong et al., 2003; Koterba & Iverson, 2009; Nagata et al., 2018; Rohlfing et al., 2006; van Schaik et al., 2020). Although it may seem that these behavioural modifications simply "reinforce" the entire action, the changes described in the characteristics of IDA are not as one-sided. They depend on the actions the person is performing (e.g., some movements are slowed down and others are sped up), their effects, and the child's characteristics, i.e., these are fine-tuned modifications (Brand et al., 2009; van Schaik et al., 2020).

Overall, it is clear that both IDS and IDA, although expressed in different modalities, show a similar pattern of modifications characterised by greater interactivity, greater affection, a higher amplitude of movements/speech frequency, greater expressiveness, simplification of content, and increased repetition.

## WAYS IN WHICH IDS AND IDA CHANGE ACCORDING TO THE AGE AND/OR DEVELOPMENTAL STAGE OF THE CHILD

IDMs are characterised by some unique features, but they are not immutable, i.e., they are adapted according to the child's age and/or abilities. Studies have systematically shown that adults subtly alter IDMs depending on many situational circumstances (e.g., van Schaik et al., 2020). These changes are mostly attributed to the child's age and/or abilities (Table 1).

***Table 1.*** *Studies documenting age-related changes in various characteristics of IDA and IDS, as well as in the temporal synchrony of IDA and IDS.*

| **IDA + IDS** | | | |
|---|---|---|---|
| **Measure** | **Age** | **Findings** | **Reference** |
| Temporal synchrony of IDS and object motion/ touch | 5-8, 9-17, 21-30 months | Mothers of prelexical infants use target words in synchrony with object motion more often than mothers of lexical infants. | Gogate et al., 2000 |
| Alignment of action descriptions (speech) with event boundaries (action) | 2.5-5.5 years | Parents of children with lower receptive vocabularies exhibit tighter synchrony than parents of children with higher receptive vocabularies. | George et al., 2019 |
| **INFANT-DIRECTED ACTIONS** | | | |
| **Measure** | **Age** | **Findings** | **Reference** |
| Gaze & object exchanges during object demonstration | 6-8 vs. 11-13 months | Shorter, more frequent gaze, and more exchanges were observed in demonstrations to older infants compared to younger infants. | Brand et al., 2007 |
| Infant-directed gaze during object demonstration | 7, 12 months | For 7-month olds, but not 12-month-olds, mothers spent more time with arbitrary- rather than enabling-sequence objects and exhibited especially close alignment of action initiations relative to completions. | Brand et al., 2013 |
| Demonstration time, characteristics of movements | 8–11, 12–23, and 24–30-months (cross-sectional and longitudinal) | Demonstration length (duration), range, and roundness of movements are influenced by age. | Rohlfing et al., 2022 |
| Object manipulation | 6-8 & 11-13 months | Infant's object manipulation dynamically affected the mother's demonstration in dyads with infants with the potential to perform the action (11-13 months), but not with infants without the potential to perform the action (6-8 months). | Fukuyama et al., 2015 |
| **INFANT-DIRECTED SPEECH** | | | |
| **Measure** | **Age** | **Findings** | **Reference** |
| Amount of IDS compared to ADS | 11, 14, 24 months (partially longitudinal) | As children get older, their caregivers use less IDS and more ADS. | Ramirez-Esparza et al., 2014 |
| SPEECH<br>Acoustic characteristics | 7-12 months and 5 years | Extent of acoustic exaggeration is significantly smaller when mothers speak to 5-year-olds compared to 1-year-olds. | Liu et al., 2009 |
| SPEECH<br>F0, positive affect (rated by adults) | 3, 6, 9, and 12 months | ✓ Utterances associated with *positive affect* tend to peak at 6 and 12 months, whereas directive utterances peak at 9 months.<br>✓ Mean F0 followed the age trend for affective utterances, and pitch range followed the trend for directive utterances. | Kitamura & Burnham, 2003 |
| SPEECH<br>F0 | Birth-5 years (longitudinal) | Infants' mean F0 decreases as a function of age. Within- and between-utterance variability in infant F0 is different before and after the onset of two-word utterances, probably reflecting the difference between linguistic and non-linguistic utterances. | Amano et al., 2006 |
| SPEECH<br>Pause duration | 5-22 months | Decrease in exaggeration of pause duration over time. | Kondaurova & Bergeson, 2011 |
| SPEECH<br>Pitch, acoustic properties | 11 & 15 months | Formants of vowels and the spectral frequency of fricatives are elevated to a greater extent for 11-month-old infants compared to 15-month-old infants, while the pitch changes are more extreme in IDS directed to 15-month-olds. | Benders, 2013 |

| | | | |
|---|---|---|---|
| SPEECH<br>Vowel duration | 0-6 months | Vowel duration changes over time, with the difference between IDS and ADS decreasing from month 3 to month 4. | Englund & Behne, 2006 |
| SPEECH<br>Speech rate | 4-16 months | Difference between IDS and ADS rates decreases across infants' first year | Narayan & McDermott, 2016 |
| SPEECH<br>Speech rate | 9-15 months (longitudinal) | Speech rate changes nonlinearly, with a shift occurring early in the multiword stage. | Ko, 2012 |
| SPEECH & LANGUAGE<br>Speech rate, words produced, length of utterances | 3, 6, 9, 12 months (longitudinal) | ✓ Maternal speech rate increases from the early stages to the end of the preverbal period.<br>✓ MLU follows a U-shaped pattern, decreasing in complexity between 3 and 9 months of age and then increasing until the end of the first year.<br>✓ IDS becomes more complex over time, but not in a linear manner, with maximum simplification occurring in the second half of the first year. | Genovese et al., 2019 |
| SPEECH & LANGUAGE<br>contour of F0, repetitiveness, timing (durations of vocalisations and pauses), tempo and MLU | 4, 12, 24 months (longitudinal) | ✓ Neonatal period is characterised by elongated pauses.<br>✓ At 4 months, the extent of pitch contouring and repetitiveness is greater than at earlier or later ages.<br>✓ Period of intense face-to-face interaction around 4 months involves more changes in certain prosodic features<br>✓ By 24 months, the duration of vocalisations and MLU becomes markedly greater. | Stern et al., 1983 |
| SPEECH & LANGUAGE<br>Utterance rate, token rate and vocabulary diversity | 1 & 3 months | ✓ Main effect of infant age on utterance rate, token rate, and vocabulary diversity. | Henning et al., 2005 |
| LANGUAGE<br>MLU, TTR | Newborns-12 years | ✓ MLU and TTR are strongly age-dependent. | Hayes & Ahrens, 1988 |
| LANGUAGE<br>Topic | 3-18 months (longitudinal) | Maternal speech changes strikingly in terms of what they talk about. At the earliest age, mothers talk a great deal about the children's feelings and experiences; at later ages, mothers talk about their activities and objects and events in the immediate environment. | Snow, 1977 |
| LANGUAGE<br>MLU, types of utterances | 4, 6, 8 months | ✓ Mothers use shorter utterances to 8-month-olds than to 4- or 6-month-olds.<br>✓ Mothers use more sentences missing subjects, verbs, or objects to 8-month-olds and more complex sentences to 4-month-olds. | Sherrod et al., 1977 |
| LANGUAGE<br>MLU | 3, 6, 9 months | Mothers reduce their MLU with increasing age. | Murray et al., 1990 |
| LANGUAGE<br>MLU, sentence type, semantic content | 8-16 months (longitudinal) | ✓ MLU decreases over time.<br>✓ Contentless utterances declines reliably as the child's productive language (and age) increases.<br>✓ Reference to absent objects across the three language periods increases. | Kavanaugh, & Jirkovsky, 1982 |

ADS, adult-directed speech; F0, fundamental frequency of speech; IDA, infant-directed action; IDS, infant-directed speech; MLU, mean length of utterance; TTR, type-token ratio.

As the child's age increases, the frequency of IDS decreases (Ramirez-Esparza et al., 2014), and numerous changes are observed in its characteristics (Liu et al., 2009). The fundamental frequency and range of fundamental frequencies of IDS are initially high, but decrease over time and reach values similar to ADS after the child begins to produce two-word utterances independently (Amano et al., 2006). In addition, pauses between utterances are also gradually reduced (Kondaurova & Bergeson, 2011) and the speech rate is increased (Genovese et al., 2019; Narayan & McDermott, 2016). Specific qualitative changes in various aspects of speech acoustics have also been documented (Benders, 2013; Englund & Behne, 2006; Kitamura & Burnham, 2003). Many changes are nonlinear (Ko, 2012), and some even show a U-shaped pattern (Genovese et al., 2019). The mean length of utterances in IDS generally decreases and then increases after the child reaches 9 months of age (Murray et al., 1990; Sherrod et al., 1977; Stern et al., 1983). A similar pattern is observed with sentence complexity (Sherrod et al., 1977). The number of repeated utterances and contentless utterances decreases (Kavanaugh & Jirkovsky, 1982). Parents tend to talk mostly about the child's feelings and activities at first, but later, they begin to talk about objects and events (Snow, 1977), and the number of utterances about objects that are not currently present increases (Kavanaugh & Jirkovsky, 1982).

These changes in adult language features are strikingly consistent with the language features that children prefer and process at different ages. For example, younger children have been shown to prefer speech with longer pauses, but this preference disappears with age (Panneton et al., 2006). In addition, children of different ages have been shown to attend to different aspects of the linguistic environment, i.e., they prefer different melodic patterns and communicative intentions of adults (Kitamura & Lam, 2009).

Although we found only a few studies that addressed age-related changes in the IDA of adults, all, but one (Brand et al., 2002), reported differences according to the child's age. In Brand et al. (2002), as the authors themselves later noted (Brand et al., 2007), no significant changes were found, probably because the measurements were too global. As a function of the child's age, parents tend to change their demonstration duration (Rohlfing et al., 2022), movement properties (Fukuyama et al., 2015; Rohlfing et al., 2022), gaze, and number of object exchanges (Brand et al., 2007). Moreover, even the coordination of IDA and IDS changes as a function of the child's age, from infancy to toddlerhood (Gogate et al., 2000) and later in preschool (George et al., 2019).

Thus, the effects of IDS and IDA on infants and children are not uniform and change with age (Han et al., 2022; Kalashnikova & Burnham, 2018; Ma et al., 2011), paralleling age-related changes in the perception of IDMs (Hayashi et al., 2001; Kitamura & Lam, 2009; Newman & Hussain, 2006).

## POTENTIAL BIOLOGICAL MECHANISMS THAT ELICIT IDMs IN ADULTS

The reason that we change communication styles when communicating with infants and young children is only partially understood. Studies have suggested that these behaviours may be observed when interacting with all communication partners who are considered to have immature or lower processing abilities (Dimitrova & Moro, 2013; Fukuyama et al., 2015; Uther et al., 2007) and/or with whom we share an emotional bond (Benders, 2013; Trainor et al., 2000). Previous studies have suggested that the use of IDS is a "spontaneous attempt to facilitate interactions with nonverbal listeners" (Ben-Aderet et al., 2017; p. 1), that it represents "a broader tendency of parents to structure interactions to support infants' development" (Brand et al., 2007; p. 204,) and that it "may be part of a more general phenomenon of adaptation to a partner during communication" (Saint-Georges et al., 2013; p.11). In the absence of data on IDA, we speculate that the same is true, i.e., that IDA also represents a specific scaffolding strategy that adults use when communicating with less competent communicators.

However, it is not clear what triggers this behaviour. There are some theories about why we

behave in a certain way when interacting with infants and some animals. One possible explanation could be the physical appearance of infants and pets. Glocker et al. (2009) found that the baby schema (a set of infantile physical characteristics, such as a round face and big eyes), which is present in infants and toddlers (Luo et al., 2011), as well as pets (Borgi et al., 2014), activates the mesocorticolimbic system, which mediates reward processing and appetitive motivation. This may be a neurophysiological mechanism by which the baby schema promotes human caregiving and likely modifications in behaviour.

The response to baby schema is mediated by oxytocin (Bos et al., 2018). Oxytocin is a neuropeptide associated with social affiliation and caregiving (for a review, see Scatliffe et al., 2019). It is sometimes referred to as the 'love hormone' or 'hormone of attachment', because it is thought to be the biological mediator of behaviours that establish and support attachment between offspring and parents (Feldman et al., 2007; Weisman et al., 2013). Oxytocin is one of the biological modulators of adult behaviours when communicating with infants. Oxytocin levels are related to both IDS and IDA. Gordon et al. (2010) found that oxytocin levels were related to the amount of affectionate parental behaviours, including IDS, expressions of positive affect, and affectionate touch. According to a study by Weisman et al. (2013), oxytocin can modulate the characteristics of IDA (e.g., parental proximity to the infant, head speed, head acceleration) in parent-infant interactions. Moreover, increased levels of oxytocin in parents may have parallel effects on the infant, increasing his or her engagement (Weisman et al., 2012). Overall, this may provide an optimal foundation for positive and joyful interactions and learning.

## SPECIFIC NEUROBIOLOGICAL RESPONSES TO IDS AND IDA IN INFANTS

Although these studies are limited in number, previous research (using various methodologies) has systematically shown that the brain of infants exhibits a unique/specific pattern of activation when listening to IDS compared to ADS and when observing IDA compared to ADA (Table 2). IDS increases brain activity (Saito et al., 2007), especially in the frontal areas (Naoi et al., 2012; Sulpizio et al., 2018). Interestingly, studies of sleeping infants (Bosseler et al., 2016; Saito et al., 2007) have suggested that IDS activates the brain of neonates to attend to utterances even when they sleep (Saito et al., 2007).

***Table 2.*** *Impact of IDS and IDA on biological functions and brain processing patterns in infants.*

| **INFANT-DIRECTED ACTIONS** | | | |
|---|---|---|---|
| **METHOD** | **AGE** | **Finding** | **Reference** |
| Electroencephalography (EEG) | 15 months | Frontal theta significantly higher in variable amplitude movements, indicating stronger attentional engagement. | Meyer et al., 2023 |
| Pupillometry | 9-18 months | Infants' pupil size increased in response to action boundaries for only IDA demonstrations. | Kosie, 2019 |
| **INFANT-DIRECTED SPEECH** | | | |
| **METHOD** | **AGE** | **Finding** | **Reference** |
| Event-related potentials (ERPs) | Newborns | Words presented in the ADS register elicited a slow positive centroparietal response in the 200–600-ms time window, whereas words in the IDS register elicited a small negative frontal response in the 700–900-ms time window. | Háden et al., 2019 |
| ERPs | (sleeping) newborns | ADS and IDS registers elicited similar ERP patterns for syllable position in an early 0–100-ms component but different ERP effects in both the polarity and topographical distribution at 200–400 ms and 450–650 ms. | Bosseler et al., 2016 |

| | | | |
|---|---|---|---|
| Near-infrared spectroscopy (NIRS) | (sleeping) newborns | IDS significantly increased brain activity compared to ADS. | Saito et al., 2007 |
| NIRS | Newborns and age-equivalent preterm infants | Compared to ADS, IDS increased activity in larger brain areas such as the bilateral frontotemporal, temporal, and temporoparietal regions, in both full-term and preterm infants. | Naoi et al., 2013 |
| Functional near-infrared spectroscopy (fNIRS) | 4-5 months | Enhanced frontal brain activation, specifically in the prefrontal cortex (involved in emotion and reward) when listening to IDS compared to ADS. | Sulpizio et al., 2018 |
| NIRS | 4-13 months | Increased activation predominantly in infants' left and right temporal areas and significantly greater activation in the frontal area when infants listened to IDS compared to ADS. | Naoi et al., 2012 |
| ERPs | 6-12 months | ✓ Enhanced N250 for formant exaggeration in IDS, more prominent in the right hemisphere.<br>✓ Increased neural synchronisation for processing formant-exaggerated speech in the delta band at frontal-central-parietal electrode sites, as well as in the theta band at frontal-central sites. | Zhang et al., 2011 |
| EEG | 7 months | Stronger low-frequency cortical tracking of the speech envelope for IDS than for ADS. | Kalashnikova et al., 2018 |
| EEG | 9 months | Higher speech-brain coherence of the prosodic stress rate for IDS than for ADS. | Menn et al., 2022 |
| EEG, heart rate | 9 months | ✓ Heart rate deceleration for IDS.<br>✓ Pattern of overall frontal EEG absolute power distinguished the intensity of emotions elicited by IDS. | Santesso et al., 2007 |
| ERPs | 9-month-olds & adults | ✓ Obligatory ERPs that code acoustic information differed for ADS and IDS.<br>✓ Presence of a mature adult-like mismatch negativity, suggesting that IDS was easier to discriminate for infants. | Peter et al., 2016 |

ADS, adult-directed speech; IDA, infant-directed action; IDS, infant-directed speech.

Apart from brain activation patterns, biological responses to IDS differ from those to ADS, as documented in terms of heart rate in infants (Santesso et al., 2007). IDS slows heart rate and thus has a calming effect.

Studies on the biological underpinnings of IDA are almost non-existent. We found only two studies on this topic (Kosie, 2019; Meyer et al., 2023), but both studies suggest that IDA may trigger different biological processing patterns than ADA.

Based on the findings presented so far, the neurobiological basis for the positive effects of IDMs on infants is associated with specific processing patterns, as determined by changes in patterns of brain activation. Moreover, studies have systematically shown that infants prefer listening to IDS over ADS (Cooper & Aslin, 1990; Fernald, 1985; Fernald & Kuhl, 1987; Werker & McLeod, 1989), as well as watching IDA over ADA (Brand & Shallcross, 2008). A preference for IDS was observed in infants who were only 2 days old (Cooper & Aslin, 1990), which could indicate that it is innate, i.e., it does not arise through experience.

The exact basis of preference for IDMs is not clear, although the results of some modelling studies suggest that the surprisal (i.e., uncertainty or variability) in stimuli (higher in infant-directed communication than adult-directed communication) might attract an infant's attention in the case of both IDS (Räsänen et al., 2018; surprisal in the prosodic contours) and IDA (Meyer et al., 2023; surprisal in each movement). Higher variability and less predictability might lead to greater attention (and thus greater learning) in infants.

## CONCLUSION

Although IDS and IDA are often considered and analysed as separate constructs, they appear to be part of the same system of IDMs produced by adults when interacting with infants and young children. We have shown that IDS and IDA have similar behavioural properties, that they trigger specific biological processes in infants, and that they change according to the infant's age and developmental stage, i.e., they are specifically adapted to the needs of the infant.

However, there are a large number of unanswered questions that need to be investigated further in future studies. For example, individual differences in parental behaviour have not been described, nor the relationship between the "intensity" of IDS and IDA (i.e., do adults with pronounced IDS also show pronounced IDA?). On the other hand, it is not clear to what extent the characteristics of IDMs themselves are influenced by the characteristics of the child, including child's temperament, responsiveness, and communication behaviour.

Because most studies on IDMs have only analysed IDS or IDA (and often using only audio or video stimuli), it remains unclear whether the effects of IDMs change when infants are exposed to multimodal, contingent stimuli in natural settings during warm, relaxed social interactions with their parents. Some studies have provided evidence that such specifically tailored, complex, and emotionally-rich social stimuli benefit the infant significantly more than the mere sum of individual stimuli. The roles of IDS and IDA in learning, especially how they contribute to learning in different modalities (e.g., the contribution of IDA to language acquisition or verbal imitation, or of IDS to joint attention and functional use of objects), whether they have the same effect on all children (i.e., presence of sex differences), and to what extent they are actually necessary for early learning are of particular interest.

The overall effect of IDMs on infant development can be observed in two different aspects: social/interactional and cognitive (processing and learning). The interrelationship between these two categories of IDM effects and the exact mechanisms of these effects are not yet fully understood. Although the primary purpose of these specific parental behaviours is probably emotional and social, the secondary purpose (scaffolding) has emerged as important support for early learning.

IDMs appear to occur spontaneously in child-adult interactions, but are also thought to be experience-dependent, rather than unconditional. This means that the actions and speech of parents are contingent on the child's response and action skills, thus creating a learning atmosphere. For instance, evidence suggests that IDSs used with children at high risk for ASD and those who are diagnosed later on include shorter utterances, more action-instructive content, fewer questions, more attention seeking, and more follow-up comments (Woolard et al., 2022). On the other hand, children with ASD exhibit low attention to IDS (Pierce et al., 2023), atypical processing of IDS (Chen et al., 2021), and likely impaired sensitivity to IDA (Shic et al., 2011). This may contribute to their problems in understanding communicative intent and turn-taking, joint attention, imitation and language development. It also raises the question of whether children with different characteristics need different forms of IDMs for optimal learning.

A better understanding of IDMs in parent-child interactions could be a good starting point to explain the mechanisms of interaction between parents and children with developmental delays/disorders and the role of IDMs in learning. It is well known that children with developmental delays/disorders can have difficulties understanding social and communicative cues in interaction, as well as difficulties in action segmentation and goal-directed action planning, which are important for understanding the purpose of everyday intentional actions and tool use. According to the current principles of early intervention, IDMs can be observed as part of everyday multimodal communication that helps children with developmental delays/disorder better understand the world and ultimately achieve better developmental outcomes. A deeper knowledge of the biological, behavioural, and functional aspects of these specific behaviours may provide us with a new perspective on the importance of early interactions and their characteristics in both typically developing children and those with developmental disorders.

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