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ARTICLE

Prosodic variation between contexts in infant-directed speech

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Abstract
Speakers consider their listeners and adjust the way they communicate. One well-studied example is the register of infant-directed speech (IDS), which differs acoustically from speech directed to adults. However, little work has explored how parents adjust speech to infants across different contexts. This is important because infants and parents engage in many activities throughout each day. The current study tests whether the properties of IDS in English vary across three in-lab tasks (sorting objects, free play, and storytelling). We analysed acoustic features associated with prosody, including mean fundamental frequency (F0, perceived as pitch), F0 range, and word rate. We found that both parents' pitch ranges and word rates varied depending on the task in IDS. The storytelling task stood out among the tasks for having a wider pitch range and faster word rate. The results depict how context can drive parents' speech adjustments to infants.

Keywords: infant-directed speech; language development; prosody

1. Introduction

Speakers commonly consider their listeners when talking and adjust the characteristics of their speech accordingly (Bell, 1984; Clark & Murphy, 1982). The concept of audience design applies to many different types of listeners, such as those who are hard-of-hearing, those who speak a different language, AI devices, and infants and children (Cohn et al., 2022; Lam & Kitamura, 2012; Uther et al., 2007). The register that adults use when interacting with infants is known as infant-directed speech (IDS). It is often characterised by having heightened pitch (perceived fundamental frequency, F0), slower rate, vowel space expansion/hyperarticulation, and longer vowel duration (Cooper & Aslin, 1990; Cristia & Seidl, 2014; Kuhl et al., 1997; but see Englund, 2018). These features of IDS are well-documented, but an open question is to what extent features of IDS vary across communicative contexts for a parent and child.

Like adults, infants do not experience language in a singular context. In day-to-day life, infants experience a variety of settings that alter the sounds, references, grammatical

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constructions, and lexical co-occurrences of a word. For example, "car" during story time can involve a narrative about an anthropomorphised car trying to win a race, whereas "car" on a road trip viewed among trucks, vans, and Sport Utility Vehicles (SUVs), can present opportunities to learn about categories (i.e., vehicles). However, the majority of studies examining IDS features have focused on a single type of interaction, spontaneous speech during play. A smaller number of studies have compared multiple contexts, usually two, such as read versus spontaneous speech (Cox et al., 2022). Thus, we have little knowledge of the ways that parents adjust acoustic features of IDS when communicating across a range of different contexts with different goals. Indeed, parents talk to their infants in many different settings with various communicative goals throughout their everyday lives, yet most studies do not take this into account. The current study addresses whether parents display acoustic variation across different contexts when talking with their infants. Studying acoustic characteristics of IDS across multiple contexts tests the degree to which audience design is sensitive to the specific communicative needs of the situation and not just defined by the type of interlocutor.

2. Acoustic features of IDS

Heightened fundamental frequency (F0), perceived as pitch, is one of the most salient features of IDS. Many studies have shown that mean pitch is typically raised in IDS relative to adult-directed speech (ADS) (Cooper & Aslin, 1990; Kuhl et al., 1997; Narayan & McDermott, 2016; Trainor & Desjardins, 2002), a finding that has been observed across a variety of languages and cultures (Broesch & Bryant, 2015; Cox et al., 2022; Hilton et al., 2022). In addition, pitch range is shown to be wider in IDS relative to ADS (Broesch & Bryant, 2015; Fernald & Simon, 1984; Xu Rattanasone et al., 2013). Increased mean pitch and pitch range in IDS are thought to serve a variety of functions such as directing infants' attention (Nencheva & Lew-Williams, 2022), highlighting important aspects of the language (Graf Estes & Hurley, 2013; Werker et al., 2007) and communicating emotion (Trainor et al., 2000).

Another well-studied acoustic characteristic of IDS is a slower speaking rate (Cooper & Aslin, 1990; Cox et al., 2022; Cristià, 2010; Fernald & Simon, 1984; Martin et al., 2016). Slower speech rate in IDS has been observed across languages and cultures (Broesch & Bryant, 2015). Part of the slower rate is segmental lengthening; for example, vowel duration, or how long speakers produce vowels, is longer relative to ADS (Cox et al., 2022; Cristia & Seidl, 2014; Hartman et al., 2017; but see Martin et al., 2016). Slower utterances (both at the word and vowel level) appear to be easier for young listeners to process because they occur on a longer timescale, giving listeners more time to parse linguistic information. For example, Zangl et al. (2005) found that infants better recognised words when presented in a slower rate of IDS, compared to those in a more challenging acoustic register (faster speech rate or low pass filtered). Other work has shown that children of parents who produce longer vowel durations and more expanded vowel spaces (i.e., referring to the size of the acoustic distinctions between vowels based on properties of the first and second formants) tend to perform better on speech discrimination tasks (Hartman et al., 2017), suggesting that parents' IDS adaptations might affect infant learning.

The work reviewed so far has demonstrated that there are distinct speech adjustments that parents make when interacting with infants. However, this literature has analysed IDS as a homogenous speaking style, not accounting for ways that parents may adjust IDS in different contexts. The following sections will address whether parents have systematic

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patterns of speech variation within IDS, adapting their speech to infants to accommodate different communicative and/or social goals across contexts.

3. Proposed motivations of IDS

While several features of IDS, such as elevated pitch and slower speech rate, appear consistently across many studies and languages, there are differing views about what drives these adaptations. Some proposals argue that these adjustments serve to direct attention (Liu et al., 2003; Nencheva & Lew-Williams, 2022; Räsänen et al., 2018), support language or cognitive development (Graf Estes & Hurley, 2013; Hartman et al., 2017; Kalashnikova & Burnham, 2018; Liu et al., 2003; Song et al., 2010), and express positive affect (Burnham et al., 2002; Kitamura & Burnham, 2003; Trainor et al., 2000; Uther et al., 2007; Werker & McLeod, 1989). There is some work suggesting that parents' intentions can be better perceived in IDS. Fernald et al. (1989) found that adults were better at characterising the intents of phrases (e.g., getting attention, game-playing, etc.) produced in IDS compared with ADS, suggesting that acoustic signatures of IDS are flexible to context.

Among these proposed motivations of IDS, directing attention has been one of the most widely discussed (Liu et al., 2003; Nencheva & Lew-Williams, 2022; Räsänen et al., 2018). The notion is that the prosodic fluctuations of IDS and the emphasis on novel words engage and sustain attention. Nencheva and Lew-Williams (2022) proposed that parents may produce new words with a higher pitch than those that are familiar, which would then direct the infant's attention towards the novel word and highlight its properties. The neuroscience literature identifies a process called entrainment, where neural activity time-locks to sensory input, which is important for processing and attention (Jones et al., 1981). In IDS, the auditory stimuli infants receive may be formulated specifically for infants, which could enhance their entrainment. Specifically, the slower rhythm of IDS may be ideal for the neural rhythms present in the infant brain (Payne et al., 2015). The attention-getting features of IDS may contribute to language development by promoting attention to the speech signal and directing infants towards the important features of language, such as new words and phrase boundaries (Nelson et al., 1989; Nencheva & Lew-Williams, 2022).

Infants' preference for IDS may be linked to its greater positive effect as well as its comforting nature, compared to other speech registers such as ADS and foreigner-directed speech (Burnham et al., 2002; Kitamura & Burnham, 2003; Uther et al., 2007; Werker & McLeod, 1989). Prosodic features of IDS such as heightened pitch, pitch variation, expanded vowel space, and slower speech rate are also thought to contribute to the greater positive effect of IDS (Benders, 2013; Burnham et al., 2002). While greater positive effect is not the main concern of the current study, these findings show that speakers are aware of the emotional and more general needs of their addressee and adjust their speech register accordingly.

Specific prosodic properties of IDS, such as enhanced pitch range and slower speech rate, have been connected to emerging language skills in infants. Raneri et al. (2020) found that parents who used slower speech rates to infants at 7 months had children with larger vocabularies at 2 years of age. Additionally, mothers' enhancement of vowel duration in English correlated with infants' expressive vocabulary, word recognition skills, and general language abilities (Hartman et al., 2017; Kalashnikova & Burnham, 2018; Liu et al., 2003; Song et al., 2010). There is some experimental evidence that IDS

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prosody can affect language learning. Graf Estes and Hurley (2013) tested the idea that IDS could facilitate word learning by presenting infants with an object labelling task in ADS or IDS. They found that infants did not learn the object labels when presented in ADS prosody but learned those same labels when presented in IDS prosody, suggesting that IDS affects the way that infants connect sounds to meaning. Thiessen et al. (2005) also found that infants were better able to segment words from fluent speech in IDS versus ADS. They proposed that IDS may sustain infants' attention better than ADS, making it easier for them to extract linguistic information from the speech stream (Thiessen et al., 2005).

4. The contexts of IDS

IDS may serve a variety of goals, such as eliciting and maintaining attention, supporting learning, or promoting positive affect. Nevertheless, it is possible that these goals do not appear within the same context or activity. When adults interact with one another, they make alterations in the way they talk and change the content of their language depending on the listener and the purpose of the interaction (Giles, 1973; Gumperz, 1977). One well-studied way that parents adapt IDS is in response to their infant's age and language proficiency (Julien & Munson, 2012; Ko, 2012). In one study by Julien and Munson (2012), adults rated the accuracy of 2- and 3-year-old children's production of fricatives and then were asked to speak as if they were responding to that child. When adults rated a child's productions as inaccurate, the adults produced longer fricatives, showing that adults' speech production is responsive to children's language proficiency. There is also evidence that as children get older and develop more advanced language skills, parents increase the complexity of the language they provide, such as producing longer utterances with greater lexical diversity to older children than to younger children (Huttenlocher et al., 2010; Rowe, 2012).

It is possible that parents also employ different features of IDS based on the needs of the setting at hand with their infant, recognising that different contexts have unique goals. For instance, during reading time, the infant hears words and a story, potentially linking what they hear with the images they see. Meanwhile, during playtime, the infant is an explorer, viewing and manipulating objects in coordination with their parents. These interaction patterns are consistent with Bell's (1984) claim that the addressee's role is not passive; their responsiveness and goals actively shape the way speakers communicate. Furthermore, a study by Spence and Moore (2003) showed that 6-month-old English learning infants can categorise different types of utterances in IDS, specifically approval and comfort utterance types. This is evidence that IDS does not only vary based on the context but also that infants are able to discriminate between these sub-styles based on the acoustic properties of IDS.

Parents may adjust salient prosodic features of IDS, like pitch and rate, depending on the type of communicative context. There is some evidence that acoustic features of IDS, specifically mean pitch, vary depending on the experimental task. For example, early work found context-related differences in both the acoustic features of IDS and utterance level characteristics such as utterance length and lexical diversity (Rondal, 1980; Stern et al., 1983). Additionally, a recent meta-analysis found that tasks consisting of spontaneous speech produced higher pitch compared to read speech across a wide range of infant ages and languages (Cox et al., 2022). This meta-analysis did not break down the analyses into

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more specific tasks, thus it is difficult to make conclusions based on just two categories (i.e., read speech and spontaneous speech).

Previous work has demonstrated that the specific type of shared activity shapes features of parents' IDS (Gergely et al., 2017) and gesture use with their infant (Puccini et al., 2010). Puccini and colleagues found that parents used more pointing gestures in a room exploration task compared to free play. Gergely et al. (2017) found acoustic differences in IDS between three different spontaneous-speech situations by Hungarian speakers and their 30-month-olds: teaching, book reading, and problem-solving. In the teaching task, speakers explained how to use a phone application. In the book reading task, speakers read a book to the infant. Finally, in problem-solving task, parents were instructed to encourage the infant to complete a task based on their age (e.g., grabbing objects, displacing objects and ordering objects). They found that parents produced the highest mean pitch in the problem-solving task, followed by storytelling and teaching which had the lowest mean pitch in IDS compared to the other tasks (Gergely et al., 2017). The authors attributed these context-related changes to parents' awareness of the attentional state of the listener (Gergely et al., 2017). While this study provides evidence that acoustic features of IDS can change based on the context, the speech samples were analysed across all words in all utterances, and there was variation in the linguistic content across tasks.

The current study focuses on specific target words in English that are repeated across tasks, allowing for a more direct comparison of how the production of the same words can vary based on the goals of different contexts. Our analysis of specific target words allows us to attribute acoustic differences to the varying contexts, rather than by the specific phrases or words used. We tested three prosodic features of IDS at the word level (average pitch, pitch range, and rate). While increased pitch range is a common feature of IDS, related work has shown variation across individuals in whether it might increase or decrease across IDS contexts, such as conversational versus read speech (Shute & Wheldall, 1999). As explained in the following section, we predict that parents' adjustments of IDS might vary depending on the context of the interactions with their infants.

5. Current study

The current study tests how the prosodic characteristics of IDS in English are tuned across different activities. Specifically, the current study investigates how parents adjust their speech to infants when producing the same word across different contexts. We analysed prosodic features of IDS (mean pitch, pitch range, and word rate) in the same set of target words across three different tasks in IDS: one where parents played with their child as they would at home (we call this a "freeplay task"), a task where parents and children worked together to sort toys into three different category bins ("sorting task"), and one where parents tell a story to narrate a wordless picture book to their child ("storytelling task"). Here, we use word rate to refer to word-level speaking rate (i.e., number of syllables per second). We analysed characteristics of pitch and rate based on previous evidence establishing the widespread modifications of these dimensions in IDS compared to ADS (Cox et al., 2022; Kitamura et al., 2001; Narayan & McDermott, 2016).

During the IDS tasks, parents were instructed to focus on a specific set of target words while completing the activities with their infant. For the free play task, parents were given

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toys that represented the target words. They were asked to label the objects but to otherwise play with their infant like they would at home. In the sorting task, parents and infants had to work together to sort those same toys into the correct bins. One bin was labelled "living things," one was "food," and one was "objects." Lastly, during the storytelling task, parents were given a wordless picture book that contained images of target items in scenes. They were prompted to make up a story aligning with the images in the book and interact with their infant as they would at home. These IDS tasks were designed so that parents had many opportunities to use the target words. Additionally, these tasks mimic activities that parents and their infants interact with during their day-to-day lives.

In this study, we predict that the type of activity will structure parents' IDS prosody based on the goals of each distinct task. The goal of the storytelling task is to engage infants' attention with the images and events in a book, which may result in exaggerated IDS features for target words, such as slower rate and higher and wider pitch variation. A unique aspect of the storytelling task is that it is the only context where parents and their infants do not have physical referents for the target words in the form of a toy. The absence of physical referents may create more ambiguity in infant's understanding of the word. Parents' attention to a referent may be very clear when they can gesture and interact with a physical object (Trueswell et al., 2016). Meanwhile, infants may find more difficulty tracking their parents' attention in contexts where the referent is more abstract – such as in our storytelling context where the only representation of the target words are images on a page. As a result of the potential ambiguity, parents may exaggerate IDS features to engage their infant. Relatedly, storytelling is more expressive compared to other spontaneous-speech contexts (Montaño & Alías, 2017). Within stories, there are many instances where speakers are conveying emotions related to the characters within the narrative. This inherently more expressive nature of storytelling may cause speakers in these contexts to produce more exaggerated speech reflected in pitch and rate, compared to other contexts (Cowie et al., 2002; Kuhn et al., 2010; Veenendaal et al., 2014; Wolters et al., 2020). We predict that these unique characteristics of the storytelling task will drive prosodic variation.

The goal of the sorting task is to encourage infants to help perform a series of actions with the toys (picking up objects and placing them in buckets), which may incite parents to produce intermediate acoustic features of IDS because it involves encouraging infants' involvement and compliance with a physical object. Gergely et al. (2017) found that parents produced the highest pitch in the problem-solving task. Since our sorting task would best mimic Gergely et al. (2017)'s problem-solving task, we predict that parents will have the highest mean pitch during the sorting task compared to the other two tasks because of the problem-solving nature of the interaction.

The goal of the free play task was to provide a naturalistic setting for word learning; parents were told to label each of the 14 objects but otherwise play with their infant as they would at home. Beech and Swingley (2024) found that parents spoke with the greatest phonetic clarity when they were first referring to an object, and the referents in that situation were also clear. They describe this as creating "conversational gems" where infants have the most informative opportunity for word learning. We predict a similar pattern with our free play task because it is the most likely time when parents will focus on word forms and referents. In particular, we predict that during this task parents will have both exaggerated pitch and slower word rate than sorting and storytelling. As a result of the free play task providing an opportunity for word

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learning, we predict that these prosodic adjustments in pitch and word rate will become less exaggerated over additional mentions of each word. It is important to note that the "vignettes" used by Beech and Swingley (2024) were taken from a corpus of at-home parent–child interactions that occurred in a variety of contexts (Cartmill et al., 2013). Our study was conducted in the lab with clear distinctions between experimental tasks, therefore our task-based predictions differ somewhat from the prior work that shaped our predictions.

Together, the storytelling, sorting, and free play tasks have distinct requirements; accordingly, we predict that the degree of IDS prosodic modifications (pitch and word rate) will reflect differences between these tasks and ways that parents support the linguistic needs of their infants. While we predict differences in mean pitch, pitch range, and speaking rate between tasks, certain features may be more context-dependent than others (Stern et al., 1983).

We designed the ADS tasks to collect repetitions of the same target words during adult interactions. In the ADS storytelling task, similar to the IDS storytelling task, the parent created a narrative containing target words and told it to an adult experimenter. In the ADS object description task, parents received the same target objects as in the IDS free play task. They were instructed to label each item and describe it in a few sentences to the experimenter. Lastly, parents completed the map task, a spatial matching game, in which the parent described the locations of images of the target objects to an experimenter. The tasks for both IDS and ADS were designed to give parents multiple opportunities to incorporate the target words in their speech in different contexts. We limited our analyses to the target words in order to examine how prosodic characteristics of a consistent set of words change across contexts.

6. Methods

6.1. Participants

The participants were 42 parents (36 females, 6 males), all native speakers of American English in California, and their infants. There were 25 10- to 12-month-olds and 17 18- to 20-month-olds (22 females, 20 males) (mean age: 14.32 months). Fourteen additional participants were excluded from the analysis due to missing audio data/recording issues (n = 11), infant fussiness (n = 2), and one case of a language screening issue.

6.2. Stimuli

Target words consisted of 14 items: apple, baby, ball, boat, bottle, camel, car, carrot, cat, cheetah, giraffe, hat, lettuce, and otter. Physical toys representing each target word were provided in a toy box (see Figure 1a and b). Some of the toys in IDS and ADS were different in order to make the toys in the ADS tasks less baby-like and more relatable for adults so the interaction would be more natural (see Figure 1b). For the storytelling task in IDS and ADS, we created two wordless picture books (see Figure 1c). Each picture book depicted a different event (going to school or going on vacation) across 20 pages. Across the pages, there were a series of actions or scenes connected with the overall theme of the story. The narrative of the event was not written on the pages, but the target items were labelled individually next to each item. Each target word appeared 3 times in each book.

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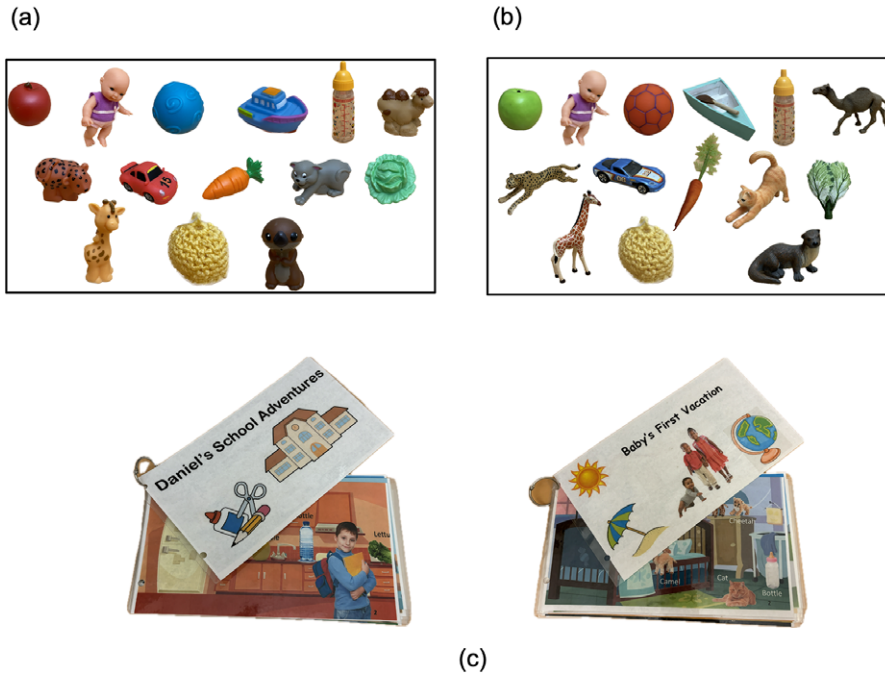


Figure 1. Toys and books used in the IDS and ADS conditions. (a) Toys used during the IDS tasks representing the 14 target words. (b) Toys used during the ADS tasks representing the 14 target words. (c) Images of the picture books used in both the IDS and ADS conditions.

6.3. Procedures

Each parent completed the register condition for IDS first, followed by the ADS (blocked). All parent–infant dyads participated in the IDS session first because pilot testing demonstrated that some infants became upset or fatigued while separated from the parent during the ADS task and could not participate in the IDS task.[1]

Within each register (IDS, ADS), the task orders were randomised. Parents completed three tasks with their infant (free play, storytelling, and sorting) to collect IDS samples, and three tasks with an experimenter (map, storytelling, and object description) to collect ADS samples. Each of the tasks lasted ~6 min. In each register (IDS, ADS) and each task, parents used the same set of target words as physical toys, appearing in books, or as isolated pictures. Figure 2 depicts each of the tasks. All sessions were video and audio recorded. For acoustic analyses, we used the audio recordings taken from a lavalier microphone clipped to the parent's shirt connected to a portable audio recorder.

[1]We recognize that the lack of counterbalancing the order of IDS and ADS tasks is a limitation of the design. However, the primary focus of this study is to compare tasks within the IDS condition and not across IDS and ADS conditions. Therefore, the order of IDS and ADS conditions has minimal effects on the interpretation of the results. Consistently presenting the IDS condition first ensured that the infants were as alert, happy, and as interested as possible when participating in the crucial conditions of the study. Note that we included word occurrence in our models to account for prior production of the target words across ADS/IDS and the contexts.

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Figure 2. Depiction of the tasks in IDS and ADS conditions.

6.3.1. IDS tasks

Free play. Parents were instructed to take each of the toys out of a box, label them, and then play with the toys as they would at home with their infant. After 4 min, a timer sounded, indicating that the parent and infant had 2 min to finish playing and put the toys back in the box.

Sorting. In this task, parents and infants had to work together to sort the toys into three different buckets with distinct labels: living things, objects, and food.

Storytelling. Parents were given one of two picture books either "Daniel's School Adventures" or "Baby's First Vacation" (Figure 1c) (assignment of IDS or ADS was counterbalanced across participants). They had to make up a story as they went through the book, with the only instruction being that they incorporate the labelled items (i.e., the 14 target words) within the story. This task lasted 6 min.

6.3.2. ADS tasks

To collect ADS samples, the parent interacted with an experimenter and was instructed to talk as they normally would with any other adult. All experimenters were female native-American English speakers from California.

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Object description. For this task, parents were asked to take each toy out of the box, say the name of the object, and then use the name in a few sentences that could consist of describing the physical appearance or what the item does or where it lives.

Map. Both the experimenter and parent were seated on either side of a privacy shield. Parents were given a sheet of paper that had images of target objects on it. The experimenter had a blank sheet of paper. The parent was tasked with describing the location of the objects to the experimenter so they could map the objects onto their blank sheet of paper. Parents were encouraged to talk about each object in as much detail as possible.

Storytelling. Parents received one of the picture books (the book not used in the IDS sample). They were asked to make up a story as they went through the book while incorporating the picture labels.

6.4. Acoustic analysis

Audio recordings were first separated by task using Praat (Boersma & Weenink, 2021) and then transcribed using an online, automatic transcription tool (https://sonix.ai/). These transcriptions were then converted to Textgrids using the *phonfieldwork* R package (Moroz, 2020). Trained research assistants listened to each of the audio files to ensure that they were of high quality. They annotated any noise (infant crying, mispronunciations, loud gasps, laughing) while also correcting the transcriptions if there were any errors. Errors and noise were omitted from the final acoustic analysis. Following this process, audio files were converted to a mono channel and a sampling rate of 16,000 Hz. These files were then force-aligned using the Montreal Forced Aligner (MFA) (McAuliffe et al., 2017). Word-level measurements (rate, mean word F0, F0 range over word) were extracted using Praat. F0 measurements were made using the autocorrelation algorithm in Praat using an adapted script (DiCanio, 2007), which calculated the mean f0 over 10 equidistant measurements within each word to generate a contour based on plausible maxima and minima f0 values by-speaker gender (female range: 150 – 350 Hz; male range: 78 – 350 Hz) (Cohn et al., 2022). We calculated mean f0 and f0 range from the f0 contour to provide a measurement that is more robust to artefacts (Cohn et al., 2022; Cohn et al., 2024). Pitch values were converted to semitones (relative to 75 Hertz) with the *hqmisc* R package (Quené, 2022). Word rate was calculated by taking the number of syllables divided by the duration for each word, resulting in the number of syllables per second (De Jong & Wempe, 2009).

6.5. Statistical analysis

We used linear-mixed effect models using the *lmer* package (Bates et al., 2015) in R to analyse the data. We analysed speech from 42 parents across 12,151 target word productions. Mean number of occurrences for each of the 14 target words analysed is shown in Table 1. We modelled each acoustic property of interest (word rate, mean pitch, pitch range) in a separate model. In each model, we first attempted to fit a complex random effects structure (with by-subject random slopes for word occurrence, task, etc.) to account for inter-subject variability (Barr et al., 2013). In the event of a convergence or singularity error, indicating the model structure is not supported by the data, we simplified the random effects structure using a systematic approach (adapted from Barr et al., 2013 and Cohn et al., 2022; e.g., removing random effects that account for 0 variance). In each model, we also tested for collinearity between the predictors with

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Table 1. Descriptive statistics (mean and SD) for the number of repetitions of the target words in each task in IDS and ADS

	IDS			ADS		
Word	Story	Free play	Sort	Story	Object	Map
Apple	3.12 (1.84)	4.7 (2.52)	5.71 (2.98)	2 (0.97)	1.67 (1.11)	5.67 (3.44)
Baby	7.33 (5.56)	13.76 (10.84)	10.12 (6.09)	4.02 (2.38)	3.05 (1.72)	6.25 (4.16)
Ball	5.05 (4.05)	6.06 (4.43)	5.65 (3.4)	2.74 (0.85)	1.9 (1.06)	5.86 (2.94)
Boat	4.28 (2.42)	3.93 (3.05)	3.81 (2.51)	3.1 (1.07)	1.91 (1.03)	6.9 (4.77)
Bottle	3.22 (1.81)	5.5 (3.95)	5 (2.93)	1.95 (0.75)	1.5 (0.62)	4.93 (2.42)
Camel	4 (1.89)	4.4 (3.39)	3.12 (1.58)	2.95 (1.24)	1.56 (0.88)	6 (2.97)
Car	4.42 (2.3)	4.62 (3.94)	4.06 (2.5)	2.98 (1.54)	1.95 (1)	6.12 (3.97)
Carrot	2.74 (1.67)	3.14 (1.68)	4.06 (2.63)	1.72 (0.8)	1.41 (0.82)	5.3 (2.57)
Cat	4.69 (3.51)	4.61 (4.16)	3.56 (2.53)	3.41 (1.45)	2 (1.24)	6.31 (4.31)
Cheetah	3.49 (2.33)	3.41 (2.37)	3.44 (2.38)	3.13 (1.2)	1.4 (0.67)	6.9 (3.92)
Giraffe	3.92 (2.46)	3.6 (1.54)	3.47 (2.11)	2.87 (1.24)	1.51 (0.79)	5.15 (2.78)
Hat	3.49 (1.6)	7.66 (3.93)	4.9 (3.26)	2.41 (1.02)	1.8 (0.94)	6.44 (3.79)
Lettuce	3.06 (1.77)	4.23 (2.54)	3.84 (2.34)	2.81 (0.92)	1.74 (1.16)	5.61 (2.71)
Otter	4.15 (2.67)	3.61 (2.23)	3.52 (2.47)	2.77 (1.22)	1.74 (1.08)	5.39 (3.38)

the *performance* R package (Lüdecke et al., 2021). The retained structure for each model is provided in the sections below.

6.6. Comparing IDS and ADS

In one set of models, we compared acoustic features of IDS and ADS, collapsing across tasks. Each model included fixed effects of condition (IDS, ADS; reference level = ADS) and previous word occurrence count (centered) for each subject across the experiment, by-speaker and by-word random intercepts, and by-speaker random slopes for word occurrence. The purpose of these analyses was to confirm that our dataset replicated previously well-established findings regarding pitch and rate in IDS.

6.7. Comparing IDS features across contexts

In another set of models, we examined word mean pitch, pitch range, and rate across tasks for the subset of IDS data (6,407 target word productions). Fixed effects included task (Free play, Sorting, Storytelling; reference level = Storytelling) and previous word occurrence count (centered) for each subject across the experiment within the IDS condition, and by-speaker and by-word random intercepts, and by-speaker random slopes for task and word occurrence for all three of the models. We tested for collinearity between the predictors with the *performance* R package (Lüdecke et al., 2021).

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7. Results

Results will be presented for each acoustic feature, beginning with pitch (mean and range) followed by-word rate. All models had low collinearity (VIF < 5), indicating that the inclusion of word occurrence was supported by the datasets.

7.1. IDS vs. ADS

The pitch model comparing IDS-ADS had a singularity error for the by-speaker random slopes for word occurrence. In the retained model[2] (output shown in Table 2), we found that condition was a significant predictor of mean F0. As seen in Figure 3a, mean F0 was significantly higher in IDS than ADS, replicating previous findings (Fernald et al., 1989; Fernald & Simon, 1984). In addition, there was a significant effect of word occurrence where the mean pitch increased across additional repetitions of the target words.

The pitch range model had a singularity error. The retained model (output shown in Table 2) did not reveal a significant difference between conditions, or a significant effect of word occurrence (Figure 3b).

The word rate model had a singularity error. In the retained model, we observed that condition was a significant predictor of word rate (model output provided in Table 2). Figure 3c shows that the rate was slower in IDS compared to ADS, replicating previous findings (Cooper & Aslin, 1994; Cox et al., 2022; Fernald & Simon, 1984; Raneri et al., 2020). In addition, there was a significant effect of word occurrence where the rate became quicker across additional repetitions of the target words.

7.2. IDS task comparisons

In the models comparing different tasks within IDS, the more robust random effects structure was not supported for either of the two pitch measures or word rate as there were singularity/convergence errors when including the by-speaker random slopes for word occurrence. The most parsimonious retained model includes by-speaker random slopes for task and by-word random intercepts.

In the retained pitch model[3] (output provided in Table 3), there was no effect of task. As seen in Figure 4a, parents did not differ in mean pitch across the storytelling, sorting, and free play tasks. However, there was a significant main effect of word occurrence, with mean pitch increasing across additional repetitions of the target words (Table 3).

In contrast, the retained pitch range model (See footnote 3) revealed an effect of task (output provided in Table 3). As seen in Figure 4b, the free play task and the sorting task had a smaller F0 range than the storytelling task ($P < 0.05$). A post-hoc analysis using pairwise comparisons (Bonferroni adjusted) did not reveal a significant difference between free play and sorting tasks (Coef = −0.06, SE = 0.13, $z = -0.47$, $P = 0.89$) (see Figure 4b). There was not a significant effect of word occurrence on pitch range.

In the retained word rate model (See footnote 3) (model output provided in Table 3), there was an effect of task. Specifically, the free play task had a slower word rate compared to the storytelling task (see Figure 4c). However, there was not a significant difference in

[2]Lmer Syntax: feature ~ condition + word_occurrence_exp.c + (1 | subject) + (1 | word).
[3]Lmer Syntax: feature ~ task + word_occurrence_cond.c + (1 + task | subject) + (1 | word)

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Table 2. Fixed and random effects parameters of the between conditions (IDS vs ADS) models

	f0 centered			Range centered			Rate centered		
Predictors	Coef	CI	*P*	Coef	CI	*P*	Coef	CI	*P*
(Intercept)	−0.78	−1.72 – 0.15	0.10	1.45	1.07 – 1.83	**<0.001**	0.11	−0.22 – 0.44	0.52
Condition [IDS]	2.52	2.37 – 2.66	**<0.001**	0.20	0.08 – 0.33	**0.001**	−0.28	−0.36 to −0.21	**<0.001**
Word occurrence exp (centered)	0.04	0.03 – 0.05	**<0.001**	−2.17 e−03	−0.01 – 0.00	0.50	0.01	0.00 – 0.01	**<0.001**
Random effects									
σ^2		15.43			11.02			4.38	
τ_{00}		7.43_{subject}			0.39_{subject}			0.27_{subject}	
		0.68_{word}			0.37_{word}			0.29_{word}	
ICC		0.34			0.06			0.11	
N		42_{subject}			42_{subject}			42_{subject}	
		14_{word}			14_{word}			14_{word}	
Observations		12151			12151			13015	
Marginal R^2 / Conditional R^2		0.074 / 0.393			0.001 / 0.065			0.005 / 0.119	

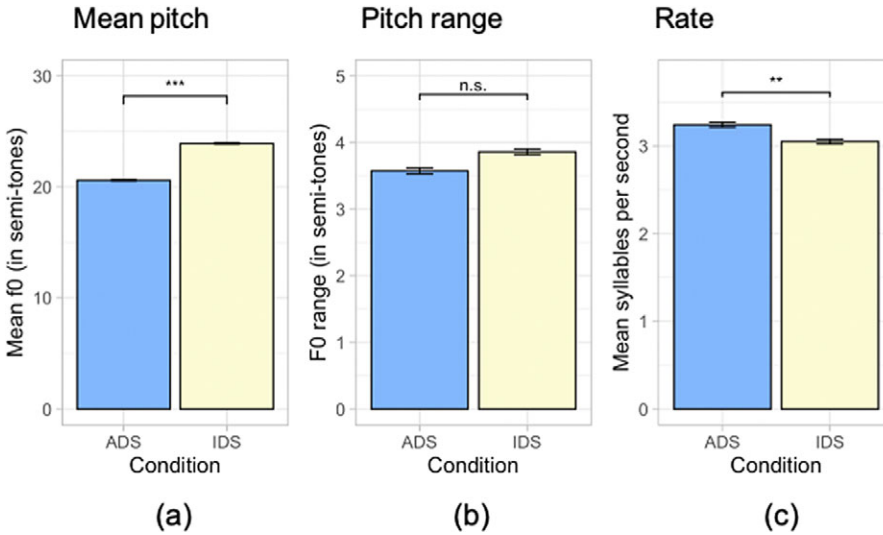


Figure 3. Pitch and rate comparisons between conditions at the word level. (a) mean F0 in semitones between addressee conditions. (b) F0 range in semitones between addressee conditions. (c) word rate between addressee conditions. Error bars show the standard error of the mean.

word rate between the sorting and storytelling tasks. A post-hoc analysis using pairwise comparisons (Bonferroni adjusted) did not reveal a significant difference between free play and sorting tasks (Coef = −0.23, SE = 0.21, $z = -1.14$, $P = 0.49$). In addition, there was a significant effect of word.

Occurrence: word rate became quicker across additional repetitions of the target words ($P < 0.001$).

7.3. Post-hoc analysis: Changes over occurrence in ADS

Additionally, we tested whether changes in word occurrence in IDS across tasks were paralleled in ADS. The models (provided in Supplementary Material) included fixed effects for task (Object description, Map, Storytelling; reference level = Storytelling) and previous word occurrence counts (centered) for each subject across the experiment within the ADS condition, and by-speaker and by-word random intercepts, as well as by-speaker random slopes for task. All three of the ADS models had a singularity error for the by-speaker random slopes for word occurrence. The retained models revealed that mean pitch, pitch range, and word rate did not significantly change over additional word occurrences in ADS ($P > 0.05$) (see Supplementary Material).

8. Discussion

The present study explored how parents adjust their speech to infants when producing the same words across different contexts. Since most studies analyse IDS within a singular context, we were interested in how the way parents talk to their children may adapt to the different activities. We analysed acoustic features (mean F0, F0 range, and word rate) of

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Table 3. Fixed and random effects parameters of the IDS between tasks models

	f0 centered			Range centered			Rate centered		
Predictors	Coef	CI	P	Coef	CI	P	Coef	CI	P
(Intercept)	1.73	0.77 – 2.68	**<0.001**	1.85	1.46 – 2.25	**<0.001**	0.03	−0.33 – 0.39	0.89
Task [free play]	−0.25	−0.70 – 0.20	0.28	−0.34	−0.57 to −0.11	**0.004**	−0.44	−0.77 to −0.11	**0.01**
Task [sort]	0.10	−0.32 – 0.53	0.63	−0.33	−0.61 to −0.04	**0.026**	−0.20	−0.53 – 0.12	0.22
Word occurrence cond (centered)	0.03	0.01 – 0.04	**0.001**	−0.01	−0.02 – 0.01	0.349	0.01	0.01 – 0.02	**<0.001**
Random effects									
σ^2		14.17			10.60			4.08	
τ_{00}		7.68_{subject}			0.34_{subject}			0.62_{subject}	
		0.65_{word}			0.38_{word}			0.24_{word}	
τ_{11}		$1.26_{\text{subject.taskfreeplay}}$			$0.06_{\text{subject.taskfreeplay}}$			$0.91_{\text{subject.taskfreeplay}}$	
		$1.05_{\text{subject.tasksort/map}}$			$0.32_{\text{subject.tasksort/map}}$			$0.90_{\text{subject.tasksort}}$	
ρ_{01}		$-0.36_{\text{subject.taskfreeplay}}$			$-0.66_{\text{subject.taskfreeplay}}$			$-0.52_{\text{subject.taskfreeplay}}$	
		$-0.23_{\text{subject.tasksort}}$			$-0.20_{\text{subject.tasksort}}$			$-0.34_{\text{subject.tasksort}}$	
ICC		0.36			0.07			0.20	
N		42_{subject}			42_{subject}			42_{subject}	
		14_{word}			14_{word}			14_{word}	
Observations		6407			6407			7075	
Marginal R^2 / Conditional R^2		0.002 / 0.360			0.003 / 0.068			0.008 / 0.206	

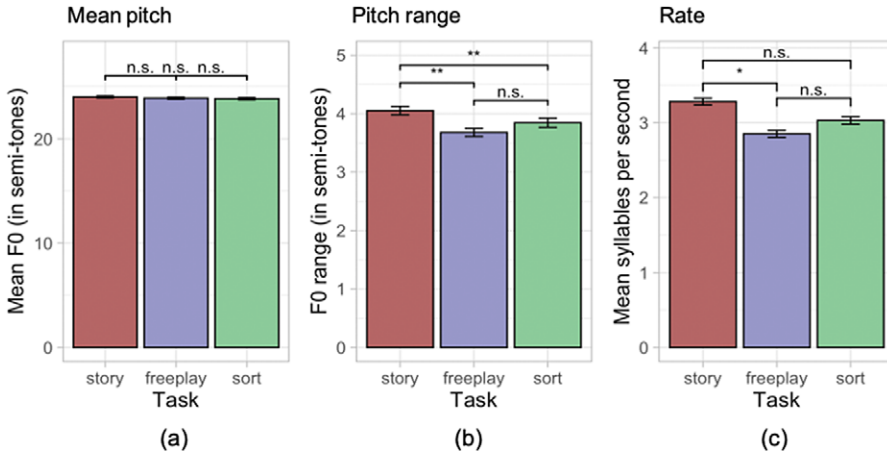


Figure 4. Pitch and word rate comparisons between IDS tasks at the word level. (a) mean F0 in semitones between tasks. (b) F0 range in semitones between tasks. (c) word rate between tasks. Error bars show the standard error of the mean.

parents' speech to their 10- to 20-month-old infants during three different tasks that shared a common set of words. We found a higher mean pitch and slower word rate in IDS than ADS, replicating previously established findings (e.g., Cooper & Aslin, 1994; Fernald & Simon, 1984). However, there was not a significant difference in pitch range between IDS and ADS.

Within IDS, we found evidence for different acoustic adjustments based on the context, specifically for our pitch range and word rate measures. Our prediction that pitch would be greatest in the sorting task based on Gergely et al. (2017) was not borne out in the current study, where we found mean pitch did not significantly vary between our tasks. However, when telling a story, parents produced larger pitch ranges compared to the free play and sorting tasks. They also produced a faster rate, relative to the sorting task. There are a few possible explanations for this pattern. First, each task had its own unique goals. In the sorting task, parents and their infants worked together to sort toys into buckets. During the free play task, parents played with their infants while labelling and describing toys. The storytelling task required parents to create their own narrative that incorporated the target words. The storytelling task was distinct from the other tasks because it involved telling a narrative and did not involve manipulating objects that represented target words. In addition, a likely goal for the parents during the storytelling task was to engage infants' attention and keep them focused on the story itself. Fernald and Kuhl (1987) found that infants listened longer to IDS than ADS when the IDS stream had exaggerated pitch contours, concluding that exaggerated pitch and infant attention go hand-in-hand. Our findings show that during storytelling parents had the widest pitch range compared to the other two tasks, suggesting that the demands and goals of a storybook might require more effort from parents to engage and sustain their infant's attention. Further explanation for this idea will be discussed below.

Storytelling is typically expressive in nature, consisting of greater variation in pitch, tone, and pauses compared to other forms of spontaneous speech (Montaño & Alías, 2017). Expressiveness, specifically variations in pitch throughout a storytelling session, is theorised to be especially important to mark significant information in a story along with

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characters' emotions, potentially aiding in reading comprehension (Cowie et al., 2002; Kuhn et al., 2010; Veenendaal et al., 2014; Wolters et al., 2020). The greater pitch range and faster word rate observed in the present study may be due to the increased expressive nature of storytelling compared to the other two experimental tasks. Since the books provided to parents were wordless picture books, we can rule out that parents were simply communicating a predetermined narrative. In addition, when stories are conveyed in a more expressive manner via pitch changes, children are better able to comprehend the details of the story itself (Mira & Schwanenflugel, 2013). Parents are potentially aware of the benefits of expressive storytelling and adjust their speech accordingly to maintain their infant's attention. Thus, it is plausible to conclude that storytelling drives increased prosodic variation in IDS, especially for pitch range and word rate. Further, it is possible that parents were more concerned about word learning and teaching in the free play task, thereby slowing their word rate to optimise learning compared to storytelling where expressiveness and infant engagement were of greater importance.

The storytelling task was also unique in that it was the only task where parents and their children did not have a physical, tactile referent for each of the target words. Instead, each target word was depicted by an image in the book. It is possible that not having a physical way to interact with each target word leads parents to use other strategies in order to engage their infants' attention with the words and referents. In this case, parents exaggerated the target words in the book by producing them with a larger pitch range. At the same time, parents produced the target words at a faster rate in storytelling than free play, making these words somewhat less clear. Previous work found that phonetic clarity (as measured by external visual clarity ratings and acoustic analyses) and referential clarity were related in IDS (Beech & Swingley, 2024). Simply put, when referents in the physical environment were easy to detect, parents' initial naming of the referent was rated as being clearer compared to referents that were not in the immediate physical environment (Beech & Swingley, 2024). The present study is consistent with these findings; referents were more obvious in the free play task than storytelling task, and this is where parents had the slowest and clearest speech when naming the target words, potentially creating more "conversational gems" (Beech & Swingley, 2024). Future studies can investigate speaker clarity and determine if there is variation between conditions and activities.

The finding that the word rate is faster in IDS storytelling may seem contradictory to the idea that a slower word rate enhances infants' word recognition. However, it does not necessarily mean that infants are *not* learning important linguistic information during storytelling. Wang et al. (2017) investigated the developmental time course of how infants adjust to variations in speech rate. They found that while 11-month-old infants were unable to distinguish between familiar and unfamiliar words in a fast speech stream, 14-month-olds were successful at doing so. In addition, the researchers found that infants relied on the speech rate of the surrounding contextual information and not just the rate of the target words (Wang et al., 2017). The mean age of the infants in the present study is 14.32 months, which means that most infants in our study can capture important linguistic information during the storytelling context, despite its faster word rate. To accommodate, infants may be using the surrounding contextual information about the story to process the target words.

Gergely et al. (2017) also found that pitch characteristics differed across tasks designed to elicit IDS, although their findings differed from ours. They found that parents produced the highest mean pitch in the problem-solving task, followed by storytelling and teaching which had the lowest mean pitch in IDS. This pattern of pitch range

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variation across tasks differs from our findings, potentially because we presented a different array of activities and goals. The present tasks mimicked activities that parents and children participate in during their everyday lives. For example, the sorting task involved behaviours that many parents and children complete during a post-playtime clean-up session. The free play task was similar to playtime, and the storytelling task was similar to storytime. These tasks relate to each other and typical activities in different ways from Gergely et al.'s problem-solving, storytelling, and teaching tasks. Additionally, our analyses considered only the target words, allowing us to (1) more accurately control for intra- and inter-speaker variation and (2) explore how the production of the same words can vary depending on the context at hand. This second point is particularly interesting because even if the same word is used across contexts, the discourse and meaning of that word can change based on the goals of communication.

The present findings identify ways that prosodic characteristics of IDS are responsive to the different types of communicative contexts that parents and children engage in. Specifically, these results provide evidence that audience design is sensitive to the context and specific communicative needs of the situation, and not just defined by the interlocutor (Bell, 1984; Clark & Murphy, 1982). Our findings suggest that parents are aware of the different communicative needs of the context and their infant and adapt their speech accordingly. This supports Lindblom's (1990) idea that listener adaptations are on a continuum, with speakers adjusting based on both the individual *and* contextual needs of the listener. Crucially, the listener may have different needs depending on the context, requiring the speaker to adjust further to accommodate those needs, leading to different levels of hypo- and hyper-articulation (Lindblom, 1990).

We also examined how parents' IDS prosody changed across repeated occurrences of the target words, particularly if there were any reduction effects present. Reduction effects refer to the phenomenon that when information is repeated, speakers tend to hypo-articulate previously mentioned words (Lindblom, 1990). For example, when adults talk to one another, acoustic features, such as speech rate and pitch, become less emphasised across repetitions of the same word (Fowler & Housum, 1987). Our findings showed that parents increased their mean pitch and word rate across repeated mentions of a word in IDS. On the one hand, the increase in mean pitch could reflect parents' attempts to capture their infant's attention and/or provide more information for word learning; rather than hypo-articulating "old" words, parents may treat all words as "new" to support their linguistic needs as a young language learner. At the same time, we saw an increased word rate with repetition in IDS, consistent with ADS. A possible explanation for this is that word rate is more responsive to infant feedback throughout an interaction than pitch may be. Work with adults has shown that when addressees demonstrate understanding of a referent, speakers produce acoustically shortened words compared to when they do not demonstrate understanding (Arnold et al., 2012). In IDS, Smith and Trainor (2008) found that mothers raised their pitch more when they were aware that increased pitch resulted in positive engagement from the infant, demonstrating that mothers are responsive to infants' attentional cues and feedback. In this study, parents might be aware of their infant's word understanding and attention over the course of the interaction via infants' actions or vocalisations, thereby supporting their consistent use of exaggerated IDS via pitch. Future studies can investigate the relationship between infant vocalisations, infant attention/engagement, and parents' prosodic adjustments. One prediction is that the between-task prosodic differences we have observed in the present study are related to infants' task-dependent attentional differences.

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The design and results of the present study provide many directions for future research. First, even though the tasks that parents and their infants completed are more diverse than previous studies, they are still within the confines of an experimental, lab setting. We predict that larger effects would occur within a more naturalistic setting, such as at-home environments. At home, there may be more clear distinctions between different activities and contexts which may reveal even greater acoustic differences between contexts. In lab settings, parents may feel uncomfortable, especially with the knowledge that they are being recorded, which can shape their speech as well (e.g., Cohn et al., 2021). Future work can analyse changes in IDS prosody in at-home recordings. Day-long home recordings would also allow us to observe how parents change the way they communicate with their infants throughout the day during different activities such as mealtime, playtime, and bedtime, each of which has distinct demands and goals. The prediction here is that parents will adjust the manner in which they speak to their infants based on the specific task, using acoustic variation as a way to differentiate between goals. Future research should also investigate the conditions that affect prosody in ADS. While we found overall differences in mean pitch and speaking rate between IDS and ADS, we did not find that IDS had a larger pitch range. This may have occurred because of the teaching and instructional style of the ADS tasks (i.e., describing objects, explaining locations and stories), a possibility that remains to be investigated.

The ADS condition could have felt unnatural to parents; reading a book to another adult and describing toys are not things adults typically do with one another. The unusual task demands may have contributed to the surprising similarity in F0 range across IDS and ADS. At the same time, IDS tasks always occurred before ADS tasks in the current study. This was to ensure that infants were in the most content and alert state as possible. However, we recognise that this is a limitation because of the potential for speaker fatigue during the ADS condition, further affecting the present acoustic analyses and interpretations.

Second, the present study does not consider the *types* of utterance functions parents are using. Past work has shown that pitch patterns differ in polar interrogatives and declaratives in IDS (Geffen & Mintz, 2017), although this work is limited. Future analyses will incorporate utterance functions (e.g., directives, interrogatives, etc.) with the acoustic analysis models to better understand other factors that may create variation within IDS. Lastly, we recognise that there may be sentence-level characteristics that shape context-related prosodic differences in IDS. Specific target words may fall in distinct positions within the utterance, affecting the way that word is produced. Previous work has found that IDS contains shorter utterances, leading to phrase-final lengthening for more words, among other characteristics (Martin et al., 2016; Wang et al., 2023). This may affect the interpretation of the pitch and word rate results. Additionally, tasks may yield varying utterance lengths. Coupled with utterance functions, future analyses will include sentence-level information about parents' utterances such as word position and utterance length to give us more nuanced information about what drives the prosodic differences between tasks that are seen in the current study.

In summary, this study considered how parents adjust their speech across different contexts when interacting with their infants. We found that parents produced a greater IDS pitch range during storytelling compared to the free play and object sorting. Parents also produced a faster word rate during storytelling compared to the free play. These findings suggest that parents adjust the way they talk to their infants based on the communicative needs of the context. In particular, engaging in a story with an infant seems to create a unique language experience. This may be due to the expressive nature of

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storytelling, especially to young children, that is supportive for reading comprehension, attention, and language development.

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